VI. POTENTIAL BENEFITS

This chapter estimates the potential benefits of advanced air bags. These benefits would be achieved from the proposed tests and new injury criteria using the pre-MY 1998 air bag systems as the base. The benefit calculation were based on limited available test data. Most of vehicles tested had passed the unbelted 30 mph rigid barrier tests. Therefore, the benefit assessment methodology assumes that manufacturers would make as few changes as possible to meet the new proposals. In addition to the benefits assessment, this chapter also provides sensitivity studies to address the impacts of an increased belt use rate and MY 1998 redesigned air bags on the benefits of advanced air bags.

The agency is proposing several alternative tests and new injury values to require manufacturers to provide advanced air bag systems that protect various sizes of occupants in a variety of frontal crash scenarios, e.g., different occupant positions, crash severities, crash pulses, and angles. The proposed tests along with the new proposed injury criteria are classified by their general objectives: (1) minimizing the risk of air bag induced fatalities and serious injuries, and (2) improving general occupant protection. Table VI-1 shows conceptually the proposed tests and their applicable target groups.

This analysis estimates the benefits for these two categories separately. Each category includes two parts: (1) benefits from fatality reduction, and (2) benefits from nonfatal MAIS 2-5 injury mitigation. The general procedure is first to identify the baseline target population and then to estimate the fatal or injury reduction rate/percentage for each test using the pre-MY 1998 injury probability as the base. Crash test results from Chapter IV are used to calculate injury probabilities. The injury reduction rate is applied to the corresponding target population which results in injury reduction benefits.

Table VI-1
Crash Tests by Impact Group

Type of Test	**Minimize Risks of Air Bag Induced Fatalities & Injuries**			**Preserve and Improve Occupant Protection From High Speed Crash Tests**			
	At-Risk Groups			**Front-Outboard Occupants**			
	Infants	**Children (1-12 Years Old)**	**Adults in Close Proximity**	**Improved Crash Testing**		**Improved Sensor Algorithm**	
				50th Percentile Male[1]	**5th Percentile Female**	**in Full Frontal**[2] **Crashes**	**in Offset Crashes**
Suppression When Present	**x**	**x**[3]					
Suppression When Out-Of-Position	**x**	**x**	**x**				
Low Risk Deployment	**x**	**x**	**x**				

Up to 30 mph Belted/Unbelted Rigid Barrier, 0 and ± 30 Degree With 50th Percentile Male				x			
Up to 30 mph Belted/Unbelted Rigid Barrier, 0 Degree With 5th Percentile Female					x		
Up to 25 mph Offset With 5th Percentile Female			x			x	x
22 to 35 mph Offset 50th Percentile Male			x			x	x
22 to 35 mph Offset 5th Percentile Female			x			x	x

1. Population includes those that can be represented by 95th percentile male dummy.
2. Full frontal crashes are defined as those with impact force from the 12 o'clock direction.
3. Because the 6 year old dummy (which weighs about 54 pounds with instrumentation) is the largest used, the test is assumed to protect children only up to 54 pounds.

The benefits of minimizing air bag risks are discussed for three at-risk groups in three parallel sections: RFCSS (infants in rear facing child safety seats), children (1-12 years old), and close-proximity adults. The benefits for improved protection from high speed crash tests are analyzed by injured body regions. The 30 mph perpendicular (0 degree) and oblique ($\pm$ 30 degrees) rigid barrier tests on restrained and unrestrained 50th percentile males and 5th percentile females with the proposed Injury Criteria Performance Limits (ICPLs) would improve overall air bag effectiveness and thus apply to all front-outboard occupants. The offset tests are intended to improve sensors and algorithms for air bag deployment decisions so that the air bag would inflate in time to provide adequate protection to occupants who otherwise would not be protected by late-deploying air bags. The agency-proposed 25 mph offset belted test and the alternative 22 to 35 mph offset unbelted test would impact out-of-position fatalities and injuries in full frontal and offset crashes. Note that full frontal crashes are defined as those crashes with an impact force from the 12 o'clock direction.

For each target population group, the analysis provides benefit estimates for the proposed tests and hypothetical air bag systems assumed to pass the proposed tests. In addition, the analysis also estimates the benefits of air bag systems assumed to pass the two alternative sets of high speed tests:

Alternative #1 includes: a) 18 to 30-mph rigid barrier, 0 degree test with unrestrained 50^{th} percentile males and 5^{th} percentile females, b) up to 30-mph rigid barrier, 0 degree tests with restrained 50^{th} males and 5th percentile females, c) 18 to 30-mph rigid barrier, $\pm$30 degree oblique tests with unrestrained 50^{th} percentile males, d) up to 30-mph rigid barrier, $\pm$30 degree oblique tests with restrained 50^{th} percentile males, and e) up to 25-mph offset with restrained 5^{th} percentile females.

Alternative #2 includes: a) up to 30-mph rigid barrier, 0 degree test with restrained 50^{th} males and 5th percentile females, b) up to 30-mph rigid barrier, $\pm$30 degree oblique tests with restrained 50^{th} percentile males, c) up to 25-mph offset with restrained 5^{th} percentile females, d) 22 to 35-mph offset tests with unrestrained 50^{th} percentile males and 5^{th} percentile females.

The hypothetical systems discussed here are linked together with potential technologies. One is a suppression type system in which air bags would not be deployed under certain situations. For these suppression systems, dynamic suppression and static weight suppression systems will be discussed. The other type is an advanced system that incorporates a higher speed threshold for air bag deployment and a multi-stage inflation system based on crash severity and belt usage. This same system, combined with a 54-pound weight sensor for suppression, will also be examined. The 54-pound weight limit is chosen to correspond to the weight represented by the 6 year old child dummy. Note that the agency does not have a preference for any particular air bag system, but is setting up tests that would allow manufacturers to use alternatives like these to meet the proposed ICPLs. Descriptions of these systems and the tests that each system would be required to pass are as follows:

Static Weight-Based Air Bag Suppression

This system is designed mainly to detect the presence of a child using weight as the threshold. Thus it applies only to passenger side air bags. The passenger side air bags would not be deployed if the front passenger seat weight sensor measures a value below a certain pre-defined weight criterion. For example, the air bag would not be deployed if the passenger weighs 54 pounds or less for the 54-pound static weight suppression system. This type of system could meet the tests for infants in rear facing child safety seats and for 3 year old and 6 year old dummies. The 6 year old dummy, with instrumentation, weighs 53.6 pounds.

Out-Of-Position Air Bag Suppression

In this system the air bag will be automatically shut off when an occupant is too close to the air bag module. Proximity sensors, e.g., ultrasound and/or infrared, may be utilized to sense the position of the occupant. This system could meet a suppression test.

Multi-Stage Inflation Based on Crash Severity and Belt Use

Driver and passenger air bags would be inflated at different power levels based on each occupant’s restraint system usage and crash severity. For purposes of this analysis, the multi-stage inflation system is defined to have the same operating characteristics as the dual power level system as stated in Table VI-2. These characteristics are analytical assumptions, not

NHTSA preferences. If equipped with a weight sensor, the system has the same definition as that stated in Table VI-2. In addition, the air bag would not be fired if the passenger weighs less than or equal to the proposed weight threshold. Note that nothing in the proposed tests require manufacturers to have multi-stage inflation capability or to have the same thresholds as in the example. The stage 1 low level deployment of this type of system is assumed, for analytical purposes, to meet the low risk deployment test for infants, children and adults in close proximity to the air bag. In addition, the second stage of the system is assumed, for analytical purposes, to meet either of the two high speed alternatives as discussed earlier.

Table VI-2
Benefit Analysis Assumptions for
Multi-Stage Inflation System Based on
Crash Severity and Restraint Use

Inflation Power	Belted (MPH)	Unbelted (MPH)
Suppression	< 18	< 14
Stage 1 Low Level Power	18-30	14-25
Stage 2 Full Power	> 30	> 25

The rest of the chapter is organized as follows: the first section (VI.A) establishes the baseline target fatal/injury population. The second section (VI.B) discusses the methodology for deriving the reduction in fatality and injury rate/percentage points. The third section (VI.C) estimates benefits first for minimizing air bag induced fatalities and serious (MAIS 3-5) injuries and then for improving occupant protection benefits from high speed crash tests. This section also estimates the impact of redesigned air bags that pass only the existing sled test. Benefits for Fatalities and MAIS 2-5 injuries are discussed separately for each relevant test, and pre-defined hypothetical air bag systems. The benefit summary section (VI.D) provides overall benefit tables for all the tests and systems. The sensitivity study section #1 (VI.E) provides changes in benefits resulting from increased safety belt usage. In addition, a parallel section (sensitivity study #2, VI.F) discusses the redesigned air bag impact on overall advanced air bag benefits. Finally, the last section (VI.G) discusses occupant behavior and its potential effects on benefits.

A. Target Population

The pre-1998 baseline population is used to estimate benefits for three reasons: 1) manufacturers introduced the MY 1998 vehicles with redesigned air bags incrementally as opposed to equipping all MY 1998 vehicles with the redesigned air bags when they were introduced. 2) Information on the extent and impact of 1998 models with redesigned air bags in the current fleet is inadequate to provide a basis for determining a full-fleet redesigned baseline estimate, and 3) the MY 1998 sled certified air bags may not be what manufacturers would have designed if they had more lead time. So, the current redesigned air bags, as found in MY 1998 vehicles, is probably not a steady, constant baseline.

For each at-risk group, the annualized fatal target population, as described in Chapter II, is projected from those actual fatal cases collected in NHTSA's Special Crash Investigation (SCI) Program as of August 1, 1999 to a projected level assuming all passenger cars and light trucks were equipped with air bags. Each at-risk MAIS 3-5 injury level was adjusted from at-risk fatalities by multiplying a corresponding factor. The factor is the ratio of MAIS 3-5 injuries to fatalities with air bags recorded as the injury source in the 1993-1998 CDS. Note that at-risk injuries do not include MAIS 2 injuries because MAIS 2 injuries are commonly cited in the crashes. It would overestimate adverse air bag effects if MAIS 2 injuries were estimated and included in the target population.

Improved occupant protection target fatalities and MAIS 2-5 injury populations from high speed crash tests are derived from the 1993-1997 CDS. Pre-MY 1998 air bags were proven to be 10 percent (not statistically significant) effective in reducing MAIS 2-5 injuries. With new tests and injury criteria, the advanced air bags would reduce these injuries further. Therefore, MAIS 2 injuries were included in the target population for the high speed tests. Similarly, the annualized front-outboard occupant fatalities from CDS then are adjusted to the 1997 FARS level to overcome the underreporting problem in CDS.

The annualized target MAIS 2-5 injury population is adjusted to the 1997 GES CDS-equivalent level to get a better national estimate. This target population is further divided into two subgroups:

1. **Adult front-outboard occupants affected by improved crash testing and injury criteria.**

Fatalities. The 15,447 adult (excluding 278 child fatalities) front-outboard occupant fatalities in frontal crashes were derived from Table II-3 (15,725 - 278 = 15,447). The 278 child (age 0-12 years old) fatalities were derived by adjusting the annualized child fatalities from 1993-1997 CDS to the 1997 FARS level. These data were derived from 1997 data, which means that incremental benefits will be compared to a fleet of vehicles equipped with pre-MY 1998 air bags. Of these 15,447, 11,988 (77.6 percent) occupants with heights of at least 65 inches are assumed to be represented by the 50th percentile male dummy, and the remaining 3,459 are assumed to be represented by the 5th percentile female dummy.

MAIS 2-5 Injuries. The 268,498 adult (excluding 3,394 child MAIS 2-5 injuries) front-outboard occupant MAIS 2-5 injuries in all frontal crashes were derived from Table II-12 (268,498 = 271,892 - 3,394). Of these 268,498, 209,918 (78.2 percent) occupants are assumed to be represented by the 50th percentile male dummy, and the remaining 58,580 are assumed to be represented by the 5th percentile female dummy. The 3,394 child (age 0-12 years old) MAIS 2-5 injuries were derived by adjusting annualized child fatalities from 1993-1997 CDS to the 1997 GES CDS-equivalent level.

2. **Front-outboard improperly positioned occupants affected by improved sensor capability.** Improperly positioned occupants are defined as those that the air bag did not help as much as it could have if they were properly positioned. These are people that were not killed or injured by the air bag, but potentially could have been saved or their injury levels could have been mitigated to a lesser severity level if the air bag characteristics were in some way improved (e.g., quicker deployment times). There are several factors that may cause an occupant to be improperly positioned, including sitting too close to the air bag, moving toward the air bag while braking, and late air bag deployment. The analysis considers that improperly positioned occupants are part of a target population that would benefit from improved sensors. The probability that an occupant would be improperly positioned is different in full frontal and offset crashes. Nusholtz[1] concluded that about 19 percent of total occupants associated with offset crashes and 1 percent of total occupants associated with full frontal crashes would be out-of-position. However, the paper didn't indicate how different the size of the "out-

[1]Nusholtz, G., Xu, Lan, & Kostyniuk, G., "Estimation of Occupant Position from Probability Manifolds of Air Bag Fire-Times", SAE # 980643, Air Bag Technology, SP-1333, SAE, 1998.

of-position" population was between fatalities and MAIS 2-5 injuries. To investigate the relationship between fatalities and injuries, data from the 1993-1997 CDS were analyzed. They showed that about 28 percent of unbelted fatalities and 36 percent of unbelted MAIS 2-5 injuries were in vehicles where drivers had made a brake maneuver to avoid a frontal crash. If these occupants were considered to be improperly positioned, the 28 percent unbelted fatalities accounted for 19 percent of all fatalities in frontal crashes. The improperly positioned MAIS 2-5 proportion was slightly less, about 14 percent of all MAIS 2-5 injuries. Because percentages are close and the Nusholtz 19 percent estimate was based on a more rigorous analysis, improperly positioned occupants are assumed, for both fatalities and MAIS 2-5 injuries, to account for 19 percent of total occupants associated with offset crashes and 1 percent of total occupants associated with full frontal crashes. Based on Stucki's[2] paper, offset crashes represent 77.9 percent of all frontal crashes.

Fatalities. Thus, there are 2,320 (34 in full frontal: 15,447*0.221*0.01; 2,286 in offset: 15,447*0.779*0.19) projected improperly positioned adult fatalities. Of these 2,320, 1,839 (27 in full frontal; 1,812 in offset) are drivers and 481 (7 in full frontal; 474 in offset) are passengers.

MAIS 2-5 Injuries. There are 40,328 (590 in full frontal: 268,498*0.221*0.01; 39,738 in offset: 268,498*0.779*0.19) projected improperly positioned adult MAIS 2-5 injuries. Of these 40,328, 31,775 (465 in full frontal; 31,310 in offset) are drivers and 8,553 (125 in full frontal;

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[2]. Stucki, Lee, "Analysis of Crash Data on Drivers With Air Bags in Frontal Crashes to Support a Frontal Offset Test Procedure", 1988-1996 National Analysis Sampling System (NASS), September 3, 1997

8,428 in offset) are passengers.

Table VI-3 summarizes the estimated baseline target population assuming all vehicles in the fleet were equipped with air bags.

Table VI-3
Target Population
Annual Estimates Assuming a Full Air Bag Fleet

	Minimize Risks of Air Bag Induced Fatalities & Injuries			Improve Occupant Protection From High Speed Crash Tests			
	At-Risk Groups			Front-Outboard Occupant Fatalities/Injuries			
	Infants	Children (1-12 Years Old)	Adults in Close Proximity	Improved Crash Testing		Improved Sensor Algorithm	
				50th Percentile Male	5th Percentile Female	In Full Frontal Crashes	In Offset Crashes
Fatalities							
Total	18	102	61	11,988	3,459	34	2,286
(Drivers)			(45)	(10,160)	(2,081)	(27)	(1,812)
(Passengers)	(18)	(102)	(16)	(1,828)	(1,378)	(7)	(474)
MAIS 2-5 Injuries							
Total	9	195	51	209,918	58,580	590	39,738
(Drivers)			(37)	(173,475)	(38,080)	(465)	(31,310)
(Passengers)	(9)	(195)	(14)	(36,443)	(20,500)	(125)	(8,428)

Source: NHTSA Special Crash Investigation (SCI) cases as of August 1, 1999, 1997 FARS, 1993-1997 CDS, and 1997 GES
Note: Fatalities derived from 1993-1997 CDS are adjusted to 1997 FARS level; Injuries are adjusted to 1997 GES CDS-equivalent level; At-risk injuries included only MAIS 3-5 injuries.

B. Overview of Method

The basic benefit estimation procedure consists of four steps: (1) establish the fatality and MAIS 2-5 injury probability (p) for each individual injury criterion (i.e., HIC, chest g's, chest deflection, Nij, etc.); (2) calculate the reduction rate/percentage (r); (3) calculate the weighted reduction rate/percentage; and (4) derive benefits. The following is a detailed description of each step.

Step 1: Establish the fatality and MAIS 2-5 injury probability (p). This step derives fatal/injury probabilities (p) for each vehicle test data included in the analysis by injury criterion (i.e., HIC, chest g's, chest deflection, Nij, etc.). The best predictor of fatal injury for chest and neck (Nij) is the AIS-5+ curve. The overwhelming majority of AIS-5 and AIS-6 injuries to the chest and neck result in a fatality. Thus, the AIS-5+ curve is a good proxy measure for fatality. Chapter III provides the algorithms for these curves, based on biomechanical data. Thus, the analysis uses AIS-5+injury curve to derive the fatality probability for Nij and CTI. The probability of a fatality, for example, for a HIC 700 is 1.7 percent (lognormal curve, see Table III-5), and for Nij=1.0 is 6.8 percent (see Figure III-5). And the corresponding MAIS 3-5 injury probability at HIC 700 for head and Nij=1 for neck is 29.5 and 23.0 percent, respectively.

Step 2: Calculate the reduction rate/percentage (r). The process is different for tests that minimize air bag risks and for those that improve air bag benefits. <u>For tests that minimize risk of air bag induced fatalities</u>, for each injury criterion, the average fatality/injury probability of the test results (p_b) is first measured against that (p_a) of the same tests after setting those tests that failed to the standard ICPLs. The reduction percentage (r) is 1 minus the ratio of p_a to p_b. That is, for each injury criterion,

$$r = 1 - p_a/p_b.$$

p_b = average fatality/injury probability of crash test results

p_a = average fatality/injury probability of crash test results after setting those with failed values to the proposed ICPL.

For example, low risk deployment reduction rates for infants were based on HIC values of four 213 tests with a 12 months old CRABI in a child safety seat. The average fatal probability (p_b) of the test results for head injury was 24.35 percent based on the lognormal curve. Three of these vehicles failed the HIC 390 ICPL and those HIC values are then set to be 390 (the head ICPL). The value p_a (0.018 percent) is the average fatal probability of this new set of four values (one value didn't change because it already passed the HIC 390). Therefore, the low risk deployment reduction rate for infants is 99.93=(1 - 0.0018/0.2435). The formula is derived based on the assumption that there is a 100 percent chance of being killed or seriously injured by pre-98 model air bags for at-risk groups and current test results corresponding to that 100 percent.

<u>For tests that improve occupant protection</u>, for each injury criterion, the actual percentage reduction (r) in the fatality and injury probabilities for each vehicle tested are calculated. Benefits are realized from improved injury criteria and the various crash test requirements (e.g., 30 mph rigid barrier with 5th percentile female and the 25 mph (or 22 up to 35 mph unbelted) belted offset test which improves the sensor algorithm). The analysis examines FMVSS 208 tests with unrestrained 50th percentile males, 35 mph offset tests with unrestrained 50th percentile males and 5th percentile females, and Transport Canada tests (25 mph offset and 30 mph rigid barrier frontal barrier with restrained 5th percentile females) that failed the proposal injury values. It estimates the fatal/injury reduction percentage for each of these tests if they just meet the proposal injury values. For example, a vehicle in the 30 mph rigid barrier test with a restrained 5th percentile female driver dummy has an Nij=1.2. Then the reduction in the percentage of fatal neck injuries for this vehicle would be 1.7 percent, which is the difference between the fatality

probability at Nij=1.2 (8.5 percent) and the fatality probability at Nij=1.0 (6.8 percent; these Nij values are put into the formula for AIS-5+ injuries shown in Figure III-5).

Step 3: Derive the weighted reduction percentage. The weighted reduction percentage is calculated using the following formula:

$$r = \Sigma\, w_i * r_i, \quad i \in \{1,2,3,...k\}$$

Where r = total percent reduction in fatality/injury probability

w_i = the weights

r_i = the reduction in fatality/injury probability

k = the total reduction percentage calculated.

Again the process and the assumptions made are different for tests that minimize air bag risks than for those that improve air bag benefits. <u>For tests that minimize risk of air bag induced fatalities</u>, w_i is the proportion of various injured body regions in the at-risk population and r_i (=1 - p_a/p_b) is the corresponding reduction percentage. For example, the reduction rate for air bags passing the low risk deployment for children 1 to 12 years old were based on the out-of-position data on a 6 years old dummy. About 29 percent (w_1) of at-risk children 1-12 years old suffered a fatal head injury, and 71 percent (w_2) of these children had a fatal neck injury. So, k=2 (the number of injury criteria assessed) and the combined fatal r is 0.9468 (=0.29*0.9172 + 0.71*0.8872) percent if based on the lognormal injury curve. The numbers 0.9172 and 0.8872 are the reduction percentages for fatal head and neck injuries as described in step 2 previously.

Note that the driver at-risk population can't separate the head and neck injuries, thus it is inappropriate to use the individual head and neck reduction rate. In this case, the fatality/injury probabilities p_a and p_b in the reduction rate formula as in step 2 represent the combined fatal/injury probabilities of head and neck. The combined fatal/injury probability are calculated by assuming that the probabilities for each body region are independent of each other and benefits for different body regions. The calculation can be determined with the following formula:

$$p_a \text{ (or } p_b\text{)} = p_1 + p_2 - p_1 * p_2$$

where p = the combined probability of p_1 (head probability) and p_2 (neck probability).

For p_b, p_1 and p_2 are the average fatality/injury probabilities of head and neck derived from the test results. While for p_a, p_1 and p_2 are the average fatality/injury probabilities of head and neck derived from the same set of tests after setting those that with failed values to ICPLs. The same procedures are applied to calculate the combined probability of an adult having a MAIS 2-5 injury.

<u>For tests that improve occupant protection</u>, the total reduction percentage for each injury criterion (head, chest, and neck) is derived from the sales weighted cumulative percentage of all of the vehicles tested. The percentage point reduction for each vehicle tested is applicable only to the proportion that each vehicle represents within the tests. In other words, by assuming that

proportion for each vehicle tested is the vehicle's proportion of on-road exposure, the reduction percentage is weighted by the vehicle's sales volume. The sum of these reduction percentages is the total reduction percentage in fatality/injury probability. The notations of the total reduction equation have a different interpretation:

$$r = \Sigma\, w_i * r_i, \quad i \in \{1,2,3,...k\}$$

Where r = total percent reduction in fatality/injury probability

w_i = the proportion of the vehicle's sales to the sales of all the vehicles tested

r_i = the reduction in fatality/injury probability from the tested level to the proposed ICPL level for each vehicle

k = the number of vehicles failing to meet the specific injury ICPL

Note that some vehicle tests had a 0.0 percent fatal/injury reduction since they already comply with proposed ICPLs. Because this process examines each individual injury criterion at different levels, it cannot use the combined probability concept. Head, neck, and chest fatal and MAIS 2-5 injuries are assessed separately, and percentage reductions are applied to head, neck, and chest fatalities/injuries, respectively. The total reduction benefit is the sum of head, neck, and chest reduction benefits.

Step 4: Derive benefits. The last step is to apply the reduction rate/percentage to the corresponding population to estimate benefits:

$$B = TP * r$$

where B = benefits (lives that would be saved or MAIS 2-5 injuries that would be mitigated)

TP = target population of the corresponding test

r = total reduction rate or reduction percentage

The following are additional adjustments that are used to calculate safety impacts:

1. All the infants killed or seriously injured by air bags suffered head injuries, therefore, only the HIC measurement is used for infants.

2. Also based on the SCI cases, all non-infant children suffered fatal or serious neck or head injuries. A combined fatality/injury reduction percentage of head (HIC) and neck injury is calculated for children.

3. The CTI, a combination of chest g's and chest deflection, injury probability curve is used to estimate the risk of chest injury. For each test type, the CTI value of those vehicles that failed to meet the standard (i.e., chest g and chest deflection) would measure against the CTI at the ICPLs. For example, if a vehicle tested with a 50^{th} male dummy had a CTI=1.17[3] at chest g 66 g's (failed) and 45 mm chest deflection, the CTI would measure against CTI=1.10 at chest g 60 g's (proposed ICPL) and 45 mm chest deflection. Note that CTI is being used for chest benefit analysis but not proposed by the agency.

[3]. CTI = chest g/90 + chest deflection/103 for the 50^{th} male dummy.

4. Tests on model year 1998 or 1999 vehicles were used only if there were no tests on pre-MY1998 models.

Table VI-4-A lists the fatality reduction rates for the target population for the proposal to minimize air bag induced fatalities. Reduction rate estimates shown are based on the Expanded Prasad/Mertz HIC curve, while those based on the lognormal curve are in parentheses. Table VI-4-B lists the injury reduction rates for the at-risk MAIS 3-5 injuries. The estimated reduction rates from low risk deployment for infants were based on the 213 crash tests on 12-month old CRABI with a deployed air bag; for children (1 and 12 years old), rates were based on the out-of-position tests with a six years old dummy right on the air bag module; for drivers, rates were based on out-of-position tests with 5th percentile females. There are no out-of-position test data for adult passengers and thus their reduction rates were adapted from children. The estimated reduction rates from 25 mph offset with a 5th percentile female were based on the Transport Canada (TC) crash test data. The estimated reduction rates from 35 mph offset unbelted crashes with 50th percentile males were based on two tests on MY 1999 vehicles. Because there were no offset tests with 50th percentile males at different speeds, the reduction rates from 30 mph offset tests with unrestrained 50th percentile males were used for the "22 to 35-mph offset with 50th percentile males" group. There were also two 35-mph offset unbelted tests with 5th percentile females. However, the percentage reduction rates for the "22 to 35 mph unbelted offset tests with 5th percentile females" were based on both TC 25 mph belted and the agency's 35 mph unbelted offset tests because the agency believes that the unbelted offset tests are more stringent than belted offset tests with the same speed. So, the benefits achieved from the 25 mph offset belted test with a 5th percentile female dummy would be included in the benefits for 22 up to 35 mph offset tests with unbelted 5th percentile females. Though 35 mph offset unbelted test might have additional benefits from improving structure integrity, this analysis does not yet address these benefits.

Table VI-4-A
Fatality Reduction Rates For At-Risk Groups

Type of Tests	Minimize Risks of Air Bag Induced Fatalities			
	Infants	**Children (1-12 Years Old)**	**Adults Passengers in Close Proximity**	**Drivers in Close Proximity**
Low Risk Deployment	99.93% (92.19%)[1]	89.59% (90.68%)	89.59%[2] (90.68%)	46.22% (46.22%)
Up to 25 mph Offset, Belted 5th Female			19.25% (19.25%)	49.75% (49.75%)
22 to 35 mph Offset, Unbelted 50th Male			0.00% (0.00%)	26.00% (26.00%)
22 to 35 mph Offset, Unbelted 5th Female			43.19% (43.19%)	60.83% (60.83%)

1. Parenthetical values based on lognormal HIC curve, non parenthetical values based on Prasad/Mertz HIC curve.
2. Percentages are assumed to be identical to the estimates for children.

Table VI-4-B
MAIS 3-5 Reduction Rates For At-Risk Groups

Type of Tests	Minimize Risks of Air Bag Induced MAIS 3-5			
	Infants	**Children (1-12 Years Old)**	**Adults Passengers in Close Proximity**	**Drivers in Close Proximity**

Low Risk Deployment	60.15% (55.78%)[1]	76.23% (76.64%)	76.23%[2] (76.64%)	53.26% (53.26%)
Up to 25 mph Offset, Belted 5th Female			26.40% (26.40%)	58.13% (58.13%)
22 to 35 mph Offset, Unbelted 50th Male			0.00% (0.00%)	34.20% (34.20%)
22 to 35 mph Offset, Unbelted 5th Female			53.86% (53.86%)	66.76% (66.76%)

1. Parenthetical values based on lognormal HIC curve, non parenthetical values based on Prasad/Mertz HIC curve.
2. Percentages are assumed to be identical to the estimates for children.

Tables VI-5-A and VI-5-B show the weighted percentage point reduction of fatal and MAIS 2-5 injury probabilities for the improved air bag protection from high speed crash tests. Reduction rate estimates shown are based on the Expanded Prasad/Mertz HIC curve, while those based on the lognormal curve are in parentheses. Based on the previous discussion for the additional CTI adjustment (#3), chest reduction percentages are derived by calculating the weighted reduction in fatality/injury probability from the tested CTI level to the CTI at the standard level. Note that no Nij values were collected for 30 mph unbelted tests with 50th percentile male dummies on pre-MY 1998 vehicle models. Based on Transport Canada 30 mph rigid barrier belted tests on 50th percentile male dummies, the test results are not very different between pre-MY 1998 and MY 1998 vehicle models. Therefore, the MY 1998 tests results are used as a baseline to calculate neck reduction percentages for this test. Also note that the agency had three 30 mph rigid barrier 30 degree oblique tests with unrestrained 50th percentile males (two on right angular and one on left angular). These tests passed the proposed ICPLs, therefore, there was no additional reduction in fatalities or injuries from vehicles that already passed the 30 mph rigid barrier perpendicular tests with 50^{th} percentile males. The estimated reduction rates from the 30 mph, rigid barrier restrained test on 5^{th} percentile female dummies were applied to the unrestrained 5^{th} percentile population as well because currently there are no pre-MY 1998 unrestrained test data on 5^{th} percentile female dummies. However, the impact would be minimal. Finally, the reduction rates for 22 to 35 mph offset tests with unbelted 5^{th} percentile females were derived based on both 25 mph offset tests with belted 5^{th} percentile females and 35 mph offset tests with unbelted 5^{th} percentile females.

All estimates are based on the assumption that all vehicles in the fleet are equipped with pre-MY 1998 air bags and there are no changes in occupant demographics, driver/passenger behavior, belt use, child restraint use, or the percent of children sitting in the front seat. The analysis uses the most current year of crash data (1997 CDS and FARS) and 1997-1998 SCI cases to derive the potential target populations that would be impacted by advanced air bags. This somewhat takes into account the current impacts of factors such as “public safety campaigns” and “air bag warning labels” that have effects on occupant safety. However, the analysis does not estimate the further potential impacts if certain trends continue. It also assumes that the sensors and other mechanical/electronic technologies are 100 percent accurate and reliable in performing their required functions (if these systems were 99.999 percent effective, it would make no difference numerically in the estimates since the target populations are not large enough to make a difference of even one life). Further, it is assumed that sales volumes of vehicles tested represent their proportional distribution of involvement in crashes. Finally, the analysis examines only a 54 pound weight sensor for RFCSS and children.

C. Benefit Estimates

Minimize Risks of Air Bag Induced Fatalities

1. Infants in RFCSS

As indicated in Table VI-3, if all vehicles in the fleet were equipped with pre-MY 1998 air bags, a total of 18 infants in RFCSS would be fatally injured by air bags annually. From a telephone

Table VI-5-A
Percentage Point Reduction of Fatal Probability for
Improved Occupant Protection From High Speed Crash Tests

Type of Tests		Front-Outboard Occupant Fatalities		
		Head	Neck(Nij)	Chest
FMVSS 208, Up to 30 mph Rigid Barrier, 0 and ± 30 Degree Unbelted 50th Percentile Male	Drivers	0.00% (0.00%)	0.00%	0.00%
	Passengers	0.00% (0.03%)	0.00%	0.00%
Up to 30 mph Rigid Barrier, 0 and ± 30 Degree Belted 50th Percentile Male	Drivers	0.00% (0.00%)	0.00%	0.00%
	Passengers	0.00% (0.00%)	0.00%	0.00%
18 to 30 mph, Rigid Barrier Unbelted 5th Percentile Female*	Drivers	0.00% (0.00%)	4.45%	0.01%
	Passengers	0.00% (0.00%)	0.78%	0.00%
Up to 30 mph, Rigid Barrier Belted 5th Percentile Female	Drivers	0.00% (0.00%)	4.45%	0.01%
	Passengers	0.00% (0.00%)	0.78%	0.00%
Up to 25 mph, Offset Belted 5th Percentile Female	Drivers	0.00% (0.00%)	9.78%	0.00%
	Passengers	0.61% (4.92%)	2.07%	0.00%
22 to 35 mph, Offset Unbelted 50th Percentile Male	Drivers	0.00% (0.00%)	1.81%	0.00%
	Passengers	0.00% (0.00%)	0.00%	0.00%
22 to 35 mph, Offset Unbelted 5th Percentile Female	Drivers	0.00% (0.00%)	14.32%	0.02%
	Passengers	0.61% (4.92%)	5.54%	0.02%

* Due to the lack of unbelted test data, belted test results were used for both belted and unbelted

population.
Note: Parenthetical values based on lognormal HIC curve, non parenthetical values based on Prasad/Mertz HIC curve.

Table VI-5-B
Percentage Point Reduction of MAIS 2-5 Injury
Probability for Improved Occupant Protection From High Speed Crash Tests

Type of Tests		**Front-Outboard Occupant MAIS 2-5 Injuries**		
		Head	**Neck(Nij)**	**Chest(CTI)**
FMVSS 208, up to 30 mph Rigid Barrier, 0 and ± 30 Degree Unbelted 50th Percentile Male	Drivers	0.00% (0.00%)	0.00%	0.00%
	Passengers	0.36% (0.14%)	0.00%	0.00%
Up to 30 mph Rigid Barrier, 0 and ± 30 Degree Belted 50th Percentile Male	Drivers	0.00% (0.00%)	0.00%	0.00%
	Passengers	0.00% (0.00%)	0.00%	0.00%
18 to 30 mph, Rigid Barrier Unbelted 5th Percentile Female*	Drivers	0.00% (0.00%)	9.90%	0.27%
	Passengers	0.00% (0.00%)	2.31%	0.28%
Up to 30 mph, Rigid Barrier Belted 5th Percentile Female	Drivers	0.00% (0.00%)	9.90%	0.27%
	Passengers	0.00% (0.00%)	2.31%	0.28%
Up to 25 mph, Offset Belted 5th Percentile Female	Drivers	0.00% (0.00%)	16.58%	0.00%
	Passengers	8.41% (3.39%)	5.33%	0.00%
22 to 35 mph, Offset Unbelted 50th Percentile Male	Drivers	0.00% (0.00%)	5.28%	0.00%
	Passengers	0.00% (0.00%)	0.00%	0.00%
22 to 35 mph, Offset Unbelted 5th Percentile Female	Drivers	0.00% (0.00%)	25.09%	0.00%
	Passengers	8.41% (3.39%)	14.27%	0.00%

* Due to the lack of unbelted test data, belted test results were used for both belted and unbelted population.
Note: Parenthetical values based on lognormal HIC curve, non parenthetical values based on Prasad/Mertz HIC curve.

survey of the public on child safety seat issues that NHTSA conducted between November 1996 and January 1997, 85 percent said they put the safety seat in the back seat, a 7 percentage point increase over 1994[4]. The infant fatality numbers in 1997-1998, which are the basis for the 18 fatalities in the target population, may reflect this changing behavior. Therefore, the analysis doesn't make a further adjustment and uses the projected 18 infants in RFCSS as the target population.

The proposed test for RFCSS includes two alternative options: suppression and low risk deployment.

Suppression

The suppression test would require that the air bag be shut off whenever a RFCSS is present. Suppression systems could be equipped with weight sensors, ultrasound, or infrared which would detect a RFCSS in the vehicle and shut off the air bag. A system that passes the test and is nearly 100 percent effective would eliminate the 18 RFCSS fatalities annually. In the case of a RFCSS, a static suppression system would be sufficient. For example, a 54-pound-limit static suppression system would suppress inflation of the air bag when the front passenger, and child

4. 1996 Motor Vehicle Occupant Safety Survey, Volume 5: Child Safety Seat Report, DOT HS 808 634, December, 1997.

safety seat, weighs 54 pounds or less. This particular static weight suppression system could prevent all 18 RFCSS fatalities. The dynamic air bag suppression system would not be needed.

Mercedes and BMW have MY 1998 production systems based on a 26 pound suppression threshold that could minimize air bag induced RFCSS fatalities. However, their sales are not enough to reduce the estimate (18*0.985=17.7, rounds to 18).

Low Risk Deployment

All the infants killed by air bags suffered head injuries. Thus, the HIC 15 value is a reasonable injury criterion to estimate the probability of an infant being fatally injured by an air bag. The agency proposes HIC 15=390 as head ICPL for infants. At 390 HIC, the probability of an infant being killed is 0.02 percent measured by Prasad/Mertz and 1.7 percent measured by lognormal curves. The estimated reduction rates for the low risk deployment were based on the HIC values from FMVSS 213 tests on 12-month old CRABI. If a low risk deployment system met 390 HIC, and this was sufficiently protective for infants, it would prevent 17-18 infant fatalities by assuming the low risk deployment would eliminate 92.19 to 99.93 percent (Table VI-4-A) of infant fatalities.

One of the systems that could be designed to pass the low risk deployment test, for example, is the multi-stage inflation system based on crash severity and belt use. As described in Table VI-2, the analysis assumes multi-stage air bags would not be inflated if the impact speed is less than 18 mph for belted occupants and the first stage air bag would be inflated with lower force. The first stage low level deployment air bag might be able to meet the low risk deployment tests. For infants, the system must pass at all inflation levels, since the agency is also concerned about infants in RFCSS in high speed crashes (not just those in the SCI cases at 25 mph delta V or less). The second stage power of the multi-stage system may fail the test for infants. This may also be difficult to accomplish with mid-mounted bags. Systems with top-mounted[5] bags would probably be more likely to pass at higher inflation levels. A total of 13 RFCSS fatalities occurred in crashes with speeds below 18 mph. If the multi-stage system successfully met the test requirements for infants, these 13 RFCSS belted fatalities would all be prevented by this system. If the first stage deployment met the HIC 15 390 requirement, then 5 RFCSS fatalities would be prevented in the first deployment stage. Altogether, the multi-stage inflation system based on crash severity could save 18 infant lives assuming the first stage deployment power passed the low risk deployment test. Because all the RFCSSs with infants in them weigh less than 30 pounds, a multi-stage inflation system equipped with a 54-pound weight sensor would also prevent all 18 infant fatalities if the system meets the proposed injury values.

In summary, as shown in Table VI-6, the rear-facing child safety seat test would have the potential to prevent 18 infant fatalities either by suppression or by the first stage meeting low risk deployment.

[5]. Top-mounted air bags deploy up towards the windshield first and then back towards the occupant. A top-mounted air bag may go over a RFCSS and possibly could meet the injury criteria. A mid-mounted air bag deploys back towards the child restraint initially and it would be very difficult to meet the injury criteria with this type of system.

Table VI-6
Estimated Fatality Reduction Benefits of Optional Tests For Rear Facing Child Fatalities

Air Bag Systems	Lives Saved Per Year
Suppression System	18
Low Risk Deployment System	17-18
- Multi-Level Inflation System*	18
- Multi-Level Inflation System with a 54 Pound Weight Suppression Option*	18

* The first stage passed the low risk deployment test.

2. **Children (1 to 12 Years Old)**

As shown in the Table VI-3, assuming all vehicles in the on-road fleet have pre-MY 1998 air bags, a total of 102 children would be projected to be killed by air bags annually. The proposed out-of-position tests using the 3-year-old dummy and the 6-year-old dummy together address the air bag-children interaction scenario. Suppression and low risk deployment testing are options to minimize air bag risk.

Suppression

The "suppression with child present" test would require the system to shut off the air bag if the sensors detect a child and ideally also would prevent all 102 child fatalities. However, the suppression test uses only 3- and 6-year-old dummies which do not represent children of all ages up to 12 years old. Here, the analysis uses 54 pounds as the threshold to differentiate children because the instrumented 6-year-old dummy weighs 54 pounds. About 81 of the 102 child fatalities are estimated to weigh 54 pounds or less. Eight (10 percent) of these children are estimated to be sitting on the lap of an adult passenger and thus would not be identified as children by a weight sensor. For this reason, the "suppression when child present" test is assumed to save only 73 (=81-8) children. However, manufacturers could possibly use a higher weight threshold (e.g., 66 pounds) or more advanced sensors to cover more children without improperly suppressing the air bag when a 5th percentile female is present. If more sophisticated sensor technologies were used and they would accurately detect children, the improved air bag systems could potentially save up to 94 (=102-8) children.

The "suppression when out-of-position" test would require that the system shut off the air bag if the proximity sensors detect that an occupant is too close to the air bag. How effective the system is depends upon whether it is a static or dynamic system. A static system would only suppress when an occupant starts in a "risk zone." A dynamic "suppression when out-of-position" system, if it works perfectly to detect out-of-position children would prevent all of these

102 child fatalities. About 13 percent of children were unbelted and weighed more than 54 pounds. These children would more likely be benefitted only by the dynamic suppression system.

Low Risk Deployment

Reduction rates were based on the agency's out-of-position tests with a 6 year old dummy right on the air bag module. As described in the methodology section, children in the SCI cases all suffered severe head and neck injury; therefore only the HIC/Nij value combination is used to assess the benefits. Applying the fatality reduction rates shown in Table VI-4-A to the 102 target child population, an air bag system passing the low risk deployment would eliminate 91-92 child fatalities. Table VI-7 presents the child fatalities that would be reduced if an air bag passes the low risk deployment test.

Table VI-7
Estimated Fatality Reduction Benefits of Low Risk Deployment Test
Children 1-12 Years Old

Target Population	102
Fatality Reduction Rate*	0.8959 - 0.9068
Lives Saved	91 - 92

* From Table VI-4-A.

The multi-stage inflation system considered in this analysis could potentially pass the low risk deployment at the first stage deployment level. To estimate the benefits that accrue from the multi-stage inflation system based on crash severity, the child data are rearranged by inflation stages corresponding to that of the system and by two different weight categories as shown in Table VI-8. These fatalities all occurred at low-to-moderate speeds (belted ≤ 30 mph, and unbelted ≤ 25 mph); hence there would be no incidents at stage 2.

Table VI-8
Target Fatal Population By Weight and Multi-Stage Air Bag Inflation Stages
Children 1-12 Years Old

Weight	Suppression*	Stage 1	Stage 2	Total
≤ 54 lbs	58	21	0	79
> 54 lbs	14	9	0	23
Total	72	30	0	102

Source: Projected number from the Special Crash Investigation cases as July 1, 1999
* See Table VI-2 for the definition of stage groups.

The multi-stage inflation system by crash severity would prevent 72 child fatalities by suppression. By applying the fatality reduction rate to the target population at the first stage, low level deployment, the system would prevent another 27 child fatalities. In total, the system could prevent 99 child fatalities. Table VI-9 presents the benefits of this system for children.

Table VI-9
Estimated Fatality Reduction Benefits of A Multi-Stage System
Children 1-12 Years Old

Lives Saved at the Suppression Stage[1]	72
The First Stage Deployment	
Target Population	30
Fatality Reduction Rate[2]	0.8959 - 0.9068
Lives Saved	27 - 27
Total Lives Saved	99 - 99

1. From Table VI-8
2. From Table VI-4-A, low risk deployment.

If the multi-stage system were equipped with a 54-pound weight sensor, 93 (see Table VI-8) children would be saved by suppression either by crash severity or by weights. Note that 8 of those children sat on an adult's lap were in crashes with impact speeds less than 14 mph. These children would be saved by suppression based on crash severity and thus included in those 93 children saved in the suppression stage. The first stage deployment, if it met the low risk deployment test, would prevent another 8 child fatalities. The multi-stage system with a 54-

pound weight suppression system would prevent 101 child fatalities. Table VI-10 summarizes the benefits of the system with a 54-pound weight suppression sensor.

Table VI-10
Estimated Fatality Reduction Benefits of A Multi-Stage System With a 54-Pound Weight Sensor
Children 1-12 Years Old

Lives Saved by the Suppression Options (by crash severity or a 54 pound limit)[1]	93		
First Stage, Low Level Deployment			
Target Population with Weight > 54 Pounds	9		
Fatality Reduction Rate[2]	0.8959	-	0.9068
Lives Saved	8	-	8
Total Lives Saved	101	-	101

1. From Table VI-8
2. From Table VI-4-A, low risk deployment

3. **Close Proximity Adults**

If all vehicles in the fleet were equipped with pre-MY 1998 air bags, a total of 61 adults would be killed annually by the air bags because they were too close to the air bag module when it deployed. Compared to their percent of the population, small stature adults (shorter than or equal to 64 inches) and older adults are disproportionately represented in adult fatalities attributed to air bags. This is because short stature or older drivers (especially females) are more likely to sit close to the steering wheel and are more prone to injury at a given force or acceleration level, and therefore are more at risk. The proposed tests using 5th percentile dummies and accompanying ICPLs provide the best safety measures for these adults in close proximity to the air bag.

Virtually all adults weigh more than 60 pounds; thus the 54-pound weight suppression system would have no effect on these adults and would not accrue any benefits for adults. Benefits are estimated separately for drivers and passengers.

Drivers

Of the 61 adults who would be killed by air bags annually, 45 are drivers. Fifteen (33 percent) of these drivers are unrestrained (including drivers with unknown belt usage); Thirty-seven (82 percent) are small stature adults with heights of 64 inches or shorter; Sixteen (36 percent) are 65 years and older.

Suppression

If the suppression-when-out-of-position test worked perfectly, it would prevent all 45 driver fatalities because the air bags would shut off if they detected out-of-position drivers in these low speed crashes. Manufacturers do not appear to be considering dynamic out-of-position systems for drivers currently.

Low Risk Deployment

Based on the fatality reduction rate shown in Table VI-4-A, the test would eliminate 46.22 percent of close proximity driver fatalities, i.e., 21 (=45*0.4622) driver fatalities could be prevented. The multi-stage system and systems with modified fold patterns or inflator might meet the low-risk deployment test.

Up to 25 MPH Offset Belted Test

This analysis also considers these close-proximity adults to be out-of-position because of late air bag firing. One reason the 25 mph offset test is proposed is to improve air bag fire time, and thus save these drivers. The reduction rate (47.95 percent) for the 25 mph offset test was based on the

TC 25 mph offset crash tests with a belted 5th percentile female dummy. Because this test is intended to improve sensor technology, therefore, the reduction is applied to all the at-risk adult drivers. The 25 mph offset test would save 22 (=45*0.4975) drivers.

22 to 35 MPH Offset Unbelted Test

As noted in the methodology section, the reduction rates for the 22 to 35 mph offset tests with 50th percentile males were based on two 35 mph offset tests on 1999 vehicle models. While, the reduction rates for 5th percentile females were based on TC 25 mph offset belted and the agency's 35 mph unbelted tests. The 22 to 35 mph unbelted tests with 50th percentile males and 5th percentile females are alternative tests also to improve sensor algorithms. So, their reduction rates from Table VI-4-A were applied to all at-risk drivers. The 22 to 35 mph unbelted tests with 50th percentile males would save 12 drivers, while the same tests with 5th percentile females would prevent 27 driver fatalities. Because these two tests are applied to the same target population, they are not additive. An air bag passing both types of tests would save a total of 27 lives, i.e., the bigger estimate of these benefits.

It is assumed that the hypothetical multi-level inflation air bag system could pass the low risk deployment at the first stage of deployment. To estimate the benefits that accrue from the multi-stage inflation system based on crash severity, drivers are classified by height and air bag inflation stages corresponding to those of the system as shown in Table VI-11. Because these fatalities all occurred at low-to-moderate speeds (both belted and unbelted $\leq$ 25 mph), there were no incidents occurring at stage 2.

Table VI-11
Target Population By Multi-Stage Air Bag Inflation Stages
Drivers in Frontal Crashes

Driver Groups	Suppression*	Stage 1	Stage 2	Total
Represented by 50th Percentile Male	13	5	0	18
Represented by 5th Percentile Female	21	6	0	27
Total	34	11	0	45

Source: Projected number from the Special Crash Investigation cases as July 1, 1999
* See Table VI-2 for the definition of the stage groups.

The suppression and low level depowering features (stage 1) of the system would prevent a total of 39 (see Table VI-12) driver fatalities based on the assumption that low power deployment would prevent 46.22 percent of driver fatalities and the system passes the low risk deployment.

Table VI-12
Estimated Fatality Reduction Benefits of A Multi-Stage System
Drivers in Close Proximity

Lives Saved by the Suppression Stage[1]	34
First Stage Deployment (passed low risk deployment)	
Target Population	11
Fatality Reduction Rate[2]	0.4622
Lives Saved	5
Total Lives Saved	39

1. From Table VI-11
2. From Table VI-4-A

Passengers

There would be a projected total of 16 adult passengers killed by air bags if the full fleet were equipped with pre-MY 1998 air bags. Thirteen (83 percent) of the 16 are small stature adults. Eleven (67 percent) of them are 65 years or older.

Suppression

The suppression when out-of-position test would save all 16 adult passenger fatalities because air bags would not be deployed if they detected an out-of-position passenger.

Low Risk Deployment

The reduction rates for the low risk deployment were assuming to be identical to those of children. The low risk deployment test would prevent 14-15 adult passenger fatalities assuming that the low risk deployment test would eliminate 89.59 to 90.68 percent of fatalities. See Table VI-13.

Table VI-13
Estimated Fatality Reduction Benefits of Low Risk Deployment Test
Adult Passengers in Close Proximity

Target Population	16
Fatality Reduction Rate[1]	0.8959 - 0.9068
Lives Saved	14 - 15

1. From Table VI-4-A.

Up to 25 MPH Offset Belted Test

The reduction rate (19.25 percent) of this test for passengers was based on TC 25 mph offset belted crash tests on 5^{th} percentile females. The offset belted test would prevent 3=(16*19.25) adult passenger fatalities.

22 to 35 MPH Offset Unbelted Test

The 22 to 35 mph unbelted tests with 50th percentile males would not accrue extra benefits for adult passengers killed by air bags, while the same tests with 5th percentile females would prevent 7 adult passenger fatalities. Overall, the 22 to 35 mph offset unbelted tests would save a total of 7 adult passengers.

The multi-level inflation air bag system may pass the low risk deployment at the first stage deployment level. The multi-stage inflation system based on crash severity would save a total of 15 passengers as shown in Table VI-14.

Table VI-14
Estimated Fatality Reduction Benefits of A Multi-Stage System
Adult Passengers in Close Proximity

Lives Saved by the Suppression Stage	8		
First Stage, Low Level Deployment			
Target Population	8		
Fatality Reduction Rate*	0.8959	-	0.9068
Lives Saved	7	-	7
Total Lives Saved	15	-	15

* From Table VI-4-A.

2. Minimize Risks of Air Bag Induced MAIS 3-5 Injuries

Air bag-induced MAIS 3-5 injuries were projected from at-risk fatalities, therefore, all the descriptive statistics (e.g., percent distribution by age, weights, and etc.) were based on fatalities for at-risk groups. In addition, all the assumptions and limitations for a specific group or a test that were discussed in the fatality benefits also apply to injury benefits. Therefore, the following injury benefit discussions for each test and air bag system do not repeat these statements

1. **Infants in RFCSS**

As indicated in Table VI-3, if all vehicles in the fleet were equipped with pre-MY 1998 air bags, a total of 9 infants in RFCSS would be seriously injured by air bags annually.

Suppression

A suppression system that passes the suppression test and is nearly 100 percent effective would eliminate the 9 RFCSS MAIS 3-5 injuries annually. In the case of a RFCSS, a static suppression system would be sufficient. For example, a 54-pound static suppression system would suppress inflation of the air bag when the front passenger plus the child safety seat weighs 54 pounds or less. This particular static weight suppression system could prevent all 9 RFCSS MAIS 3-5 injuries.

Mercedes and BMW have MY 1998 production systems based on a 26 pound suppression threshold that could prevent air bag induced RFCSS MAIS 3-5 injuries. However, their sales are not enough to reduce the estimate (9*0.985=8.9, rounds to 9).

Low Risk Deployment

As discussed in the RFCSS fatality section, the HIC 15 value is the only injury criterion used to estimate the probability of an infant being seriously injured by an air bag. The estimated reduction rates for the low risk deployment were based on the HIC 15 values from FMVSS 213 tests on 12-month old CRABI. The MAIS 3-5 injury reduction rate (Table VI-4-B) is 60.15 percent measured by Prasad/Mertz and 55.78 percent measured by lognormal curves. A low risk deployment system, as shown in Table VI-15, would reduce 5 infant MAIS 3-5 injuries.

Table VI-15
Estimated MAIS 3-5 Injury Reduction Benefits of Low
Risk Deployment Test RFCSS

Target Population	9
Injury Reduction Rate[1]	0.5578 - 0.6015
Injuries Reduced	5 - 5

1. From Table VI-4-B.

The multi-stage inflation system would reduce 7 infant MAIS 3-5 injuries by the suppression stage. Altogether, as shown in Table VI-16 the multi-stage inflation system based on crash severity could prevent 8 infant MAIS 3-5 injuries assuming that the first stage power passed the low risk deployment test. Because all the RFCSSs and infants weigh less than 30 pounds, a multi-stage inflation system equipped with a 54-pound weight sensor would also prevent all 9 infant MAIS 3-5 injuries.

Table VI-16
Estimated Fatality Reduction Benefits of A Multi-Stage System
Rear Facing Child MAIS 3-5 Injuries

Injury Reduced by the Suppression Options (by Crash Severity)	7
First Stage, Low Level Deployment	
Target Population with Weight > 54 Pounds	2
Injury Reduction Rate[1]	0.5578 - 0.6015
Injury Reduced	1 - 1

Total Lives Saved	8 - 8

1. From Table VI-4-B, low risk deployment

In summary, as shown in Table VI-17, the rear-facing child safety seat test would have the potential to prevent 9 infant injuries by suppression, 5 injuries by low risk deployment, and 8 injuries by the multi-level inflation system.

Table VI-17
Estimated Injury Reduction Benefits of Optional Tests For Rear Facing Child MAIS 3-5 Injuries

Air Bag Systems	**MAIS 3-5 Injuries Reduced Per Year**
Suppression System	9
Low Risk Deployment System	5
- Multi-Level Inflation System	8
- Multi-Level Inflation System with a 54 Weight Sensor Options	9

2. **Children (1 to 12 Years Old)**

A total of 195 children would be projected to be seriously injured by air bags annually. Suppression and low risk deployment testing are options to minimize air bag risk.

Suppression

The "suppression with child present" test would require the system to shut off the air bag if the sensors detect a child and ideally also would prevent all 195 child MAIS 3-5 injuries. Of these 195 children, 155 weighed less than or equal to 54 pounds. Of these 155, 15 children are estimated to be sitting on an adults' lap when the crash occurred and these children would not be detected as a child weighing less than 54 pounds. The 54 pound suppression options would reduce 140 (=155-15) child serious injuries. If manufacturers voluntarily install a higher weight threshold (e.g., 66 pounds) suppression system, it would cover more children without improperly suppressing the air bag when a 5th percentile female is present. Or, if more sophisticated sensor technologies were used and they would accurately detect children, the improved air bag systems could potentially prevent up to 180 (=195-15) child MAIS 3-5 injuries.

The "suppression when out-of-position" test would require that the system shut off the air bag if the proximity sensors detect that a child is too close to the air bag; if it works perfectly it would prevent all of these 195 child MAIS 3-5 injuries.

Low Risk Deployment

As described in the fatal benefit section, only the HIC/Nij value combination is used to assess the benefits. Applying the injury reduction rates as shown in Table VI-4-B to the 195 target child injury population, an air bag system passing the low risk deployment test would eliminate 149 air bag-induced injuries. Table VI-18 presents the child injuries that would be reduced if an air bag passes the low risk deployment test.

Table VI-18
Estimated MAIS 3-5 Injury Reduction Benefit of Low Risk Deployment Test
Children 1-12 Years Old

Target MAIS 3-5 Injury Population	195
Injury Reduction Rate*	0.7623 - 0.7664
Injuries Reduced	149 - 149

* From Table VI-4-B.

To estimate the benefits that accrue from the multi-stage inflation system based on crash severity, the child data are rearranged by inflation stages corresponding to that of the system and by two different weight categories as shown in Table VI-19. Note that the injury distribution was based on the distribution of fatalities. These injuries all occurred at low-to-moderate speeds (belted ≤ 30 mph, and unbelted ≤ 25 mph); hence there were no incidents at stage 2.

Table VI-19
Target MAIS 3-5 Injury Population By Weight and Multi-Stage Air Bag Inflation Stages
Children 1-12 Years Old

Weight	Suppression*	Stage 1	Stage 2	Total
≤ 54 lbs	111	40	0	151
> 54 lbs	27	17	0	44
Total	138	57	0	195

Source: the Special Crash Investigation cases as July 1, 1999 and 1993-1998 CDS.
* See Table VI-2 for the definition of stage groups.

The multi-stage inflation system by crash severity would reduce 138 child MAIS 3-5 injuries by suppression. As discussed previously, by applying the injury reduction rate (Table VI-4-B) to the target population at the first stage, low level deployment, the system would prevent another 43-44 child injuries. In total, the system could reduce 181-182 child MAIS 3-5 injuries. Table VI-20 presents the injury benefits of this system for children.

Table VI-20
Estimated MAIS 3-5 Injury Benefits of A Multi-Stage System
Children 1-12 Years Old

Injuries Reduced at the Suppression Stage[1]	138
The First Stage Deployment	
Target Population	57
Injury Reduction Rate[2]	0.7623 - 0.7664
Injuries Reduced	43 - 44
Total Injuries Reduced	181 - 182

1. From Table VI-19
2. From Table VI-4-B, low risk deployment.

If the system were equipped with a 54-pound weight sensor, 178 child injuries would be prevented by suppression either by crash severity or by weights (27 by crash severity; 151 by the 54 pound weight suppression option). The first stage deployment, if it met the low risk deployment test, would prevent another 13 child injuries. In total, the multi-stage system with a 54-pound weight suppression system would prevent 191 child MAIS 3-5 injuries. Table VI-21 summarizes the benefits of the system with a 54-pound weight suppression sensor.

Table VI-21
Estimated MAIS 3-5 Injury Reduction Benefits of A Multi-Stage System
With a 54-Pound Weight Sensor
Children 1-12 Years Old

Injuries Reduced by the Suppression Options (by crash severity or a 45 pound limit)[1]	178
First Stage, Low Level Deployment	
Target Population with Weight > 54 Pounds	17
Injury Reduction Rate[2]	0.7623 - 0.7664

Injuries Reduced	13 - 13
Total Injuries Reduced	191 - 191

1. From Table VI-8
2. From Table VI-4-B, low risk deployment
3. Close Proximity Adults

If all vehicles in the fleet were equipped with pre-MY 1998 air bags, a total of 51 adults would be seriously injured by the air bags because they were too close to the air bag module when it deployed. Of the 51 adults MAIS 3-5 injuries, 37 were drivers and 14 were front-outboard passengers.

Drivers

Suppression

If the suppression when out-of-position test worked perfectly, it would reduce all 37 driver injuries because the air bags would shut off if they detected out-of-position drivers in these low speed crashes.

Low Risk Deployment

Based on the injury reduction rate shown in Table VI-4-B, the test would eliminate 53.26 percent of close proximity driver MAIS 3-5 injuries, i.e., 20 (=37*0.5326) driver injuries would be reduced. The multi-stage system and systems with modified fold patterns or inflator might meet the low-risk deployment test.

Up to 25 MPH Offset Belted Test

The up to 25 mph offset tests would eliminate 58.13 percent of close proximity driver MAIS 3-5 injuries, i.e., 22 (=37*0.5813) driver injuries would be reduced.

22 to 35 MPH Offset Unbelted Test

The 22 to 35 mph offset unbelted tests with 50th percentile males would eliminate 12 (=47*0.2600) driver MAIS 2-3 injuries. While same tests with 5th percentile females would prevent 27 driver MAIS 2-3 injuries. As noted in the fatality section, the reduction rates for the 22 to 35 mph offset tests with unbelted 50th percentile males were based on two 35 mph tests on 1999 vehicle models. Overall, if an air bag system passing the 22 to 35 mph offset unbelted tests would prevent 27 MAIS 2-5 injuries for drivers.

For the multi-stage inflation system based on crash severity, driver injuries are tabulated by height and air bag inflation stages corresponding to those of the system as shown in Table VI-22. Because these injuries all occurred at low-to-moderate speeds (both belted and unbelted $\leq$ 25 mph), there were no incidents occurring at stage 2.

Table VI-22
Target Driver MAIS 3-5 Injury Population By Multi-Stage Air Bag Inflation Stages

Driver Groups	Suppression*	Stage 1	Stage 2	Total
Represented by 50th Percentile Male	11	4	0	15
Represented by 5th Percentile Female	17	5	0	22
Total	28	9	0	37

Source: the Special Crash Investigation cases as July 1, 1999; 1993-1998 CDS
* See Table VI-2 for the definition of the stage groups.

The suppression and low level depowering features (stages 1) of the system would reduce a total of 33 (see Table VI-23) driver MAIS 3-5 injuries based on the assumption that low power deployment would prevent 53.26 percent of driver injuries and the system passes the low risk deployment tests.

Table VI-23
Estimated MAIS 3-5 Injury Reduction Benefits of A Multi-Stage System
Drivers in Close Proximity

Injuries Reduced by the Suppression Stage[1]	28
First Stage Deployment (passed low risk deployment)	
Target Population	9
Injury Reduction Rate[2]	0.5326
Injuries Reduced	5
Total Injuries Reduced	33

1. From Table VI-23
2. From Table VI-4-B

Passengers

There would be a projected total of 14 adult passenger MAIS 3-5 injuries.

Suppression

The suppression when out-of-position test would prevent all 14 adult passenger injuries because air bags would not be deployed if they detected an out-of-position passenger.

Low Risk Deployment

The low risk deployment test would prevent 11 (=14*0.7623) adult passenger MAIS 3-5 injuries assuming that low risk deployment test would eliminate 76.23 percent of injuries.

Up to 25 MPH Offset Belted Test

The up to 25 mph offset tests would prevent 4 (=14*0.2640) adult passenger MAIS 3-5 injuries assuming that the low risk deployment test would eliminate 0.2640 percent of injuries.

22 to 35 MPH Offset Unbelted Test

The 22 to 35 mph offset tests with unbelted 50th percentile males would not accrue additional benefits for adult passenger at-risk group. While, the 22 to 35 mph offset tests with unbelted 5th percentile female would eliminate 53.86 percent of close proximity adult passenger MAIS 3-5 injuries, i.e., 8 (=14*0.5387) adult passenger MAIS 3-5 injuries would be prevented. Together, the 22 to 35 mph offset unbelted tests would prevent 8 passenger MAIS 3-5 injuries.

The multi-level inflation air bag system may pass the low risk deployment at the first stage deployment level. The multi-stage inflation system based on crash severity and belt use would prevent 12 of these passenger injuries as shown in Table VI-24

Table VI-24
Estimated MAIS 3-5 Injury Reduction Benefits of A Multi-Stage System
Adult Passengers in Close Proximity

Injuries Reduced by the Suppression Stage	7
First Stage, Low Level Deployment	
Target Population	7
Injury Reduction Rate*	0.7623

Injuries Reduced	5
Total Injuries Reduced	12

* From Table VI-4-B.

Benefits From Improved Occupant Protection From High Speed Crash Tests

1. Fatalities

As described in the method section, the reduction percentage is calculated for each test that failed the proposal injury values. Benefits are derived by applying the reduction percentages to the appropriate target population as shown in Table VI-25. The analysis gave precedence to head injuries if an occupant had a maximum head, chest injury, and neck injury at the same AIS level. These cases were categorized in the head group.

Table VI-25
Target Populations for Improved Occupant Protection From High Speed Crash Tests
Front-Outboard Adult Occupant Fatalities in Frontal Crashes

	Fatalities Represented by 50th Percentile Male			**Fatalities Represented by 5th Percentile Female**			**Fatalities Potentially Impacted by Improving Sensor Algorithm**		
	Head	**Neck**	**Chest**	**Head**	**Neck**	**Chest**	**Head**	**Neck**	**Chest**
Drivers	3,861	1,524	3,353	791	312	687	699	276	607
Belted	1,365	539	1,185	280	110	243	247	98	215
Unbelted	2,496	985	2,168	511	202	444	452	178	392
Passengers	695	274	603	524	207	455	183	72	159
Belted	239	94	208	180	71	156	63	25	54
Unbelted	456	180	395	344	136	299	120	47	105
Total	4,556	1,798	3,956	1,315	519	1,142	882	348	766
Belted	1,604	633	1,393	460	181	399	310	123	269
Unbelted	2,952	1,165	2,563	855	338	743	572	225	497

Source: 1993-1997 CDS; 1997 FARS
Note: Fatalities were derived from 1993-1997 CDS and adjusted to 1997 FARS level.

The fatal reduction percentages shown in Table VI-5-A are applied to the population in Table VI-25. Table VI-26 shows the fatality reduction benefits. An air bag that passes the 30 mph, unbelted 5th percentile female test would save 10 lives, while the belted test would save 6 lives. The 25 mph offset, belted 5th percentile female test would save 29 to 37 lives. The 22 to 35 mph offset, unbelted 50th percentile male tests together would save 5 lives; the same tests with 5th percentile females would save about 45-53 lives.

Note that tests with no additional benefits beyond those already achieved (total 3,253 lives annually) from Pre-MY 1998 air bags are shown as 0 in Table VI-26. For example, the 0 benefits for the 30 mph rigid barrier tests with 50th percentile males indicates that this type test would not accrue additional benefits. All vehicles tested with 50th percentile male dummies met the new neck injury criteria and the other new ICPLs. Also note that the reduction percentages for the 30 mph rigid barrier unbelted test with a 5th percentile female dummy were adapted from the belted tests. It is therefore possible that this analysis presents a conservative estimate of the benefits of meeting this test.

2. Impact of the Sled Test

The above discussion reflects added safety benefits of the proposed requirements measured from the pre-MY 1998 base. Some commenters have argued that the existing sled test, which was initiated in 1998 as a temporary measure to address the problem of air bag injuries, should be retained and made a permanent part of FMVSS 208. However, if the existing sled test were retained, it would provide fewer benefits to persons not in the at-risk group than either of the alternatives considered in this SNPRM, or the pre-MY 1998 base requirements.

Table VI-26
Fatalities Reduced by Test Types for
Improved Occupant Protection From High Speed Crash Tests

		Head	Neck	Chest	Total
18 to 30 mph, Rigid Barrier, 0 and ± 30 Degree Unbelted 50th Percentile Male	**Drivers**	0 (0)	0	0	0* (0*)
	Passengers	0 (0)	0	0	0* (0*)
	Total	0 (0)	0	0	0* (0*)
Up to 30 mph, Rigid Barrier, 0 and ± 30 Degree Belted 50th Percentile Male	**Drivers**	0 (0)	0	0	0* (0*)
	Passengers	0 (0)	0	0	0* (0*)
	Total	0 (0)	0	0	0* (0*)
18 to 30 mph, Rigid, 0 Degree Unbelted 5th Percentile Female**	**Drivers**	0 (0)	9	0	9 (9)
	Passengers	0 (0)	1	0	1 (1)
	Total	0 (0)	10	0	10 (10)
Up to 30 mph, Rigid Barrier, 0 Degree Belted 5th Percentile Female	**Drivers**	0 (0)	5	0	5 (5)
	Passengers	0 (0)	1	0	1 (1)
	Total	0 (0)	6	0	6 (6)

* No additional benefits beyond those already achieved from Pre-MY 1998 air bags.
** The unbelted fatal reduction percentage is assumed to be identical to that of belted.
Note: Parenthetical values based on lognormal HIC curve, Non parenthetical values based on Prasad/Mertz HIC curve.

Table VI-26 - Continued
Fatalities Reduced by Test Types for
Improved Occupant Protection From High Speed Crash Tests

		Head	Neck	Chest	Total
Up to 25 mph, Offset, Belted 5th Percentile Female	**Drivers**	0 (0)	27	0	27 (27)
	Passengers	1 (9)	1	0	2 (10)
	Total	1 (9)	28	0	29 (37)
22 to 35 mph, Offset, Unbelted 50th Percentile Male	**Drivers**	0 (0)	5	0	5 (5)
	Passengers	0 (9)	0	0	0 (0)
	Total	0 (9)	5	0	5 (5)
22 to 35 mph, Offset, Unbelted 5th percentile Female	**Drivers**	0 (0)	40	0	40 (40)
	Passengers	1 (9)	4	0	5 (13)
	Total	1 (9)	44	0	45 (53)

* No additional benefits beyond those already achieved from Pre-MY 1998 air bags.
** The unbelted fatal reduction percentage is assumed to be identical to that of belted.
Note: Parenthetical values based on lognormal HIC curve, Non parenthetical values based on Prasad/Mertz HIC curve.

To estimate the impact of the retaining the sled test, three different approaches were examined. These approaches reflect the fact that current vehicle fleets have not yet been redesigned based on a sled test requirement. Instead, most vehicles are designed based on the 30 mph frontal barrier test required on all pre-MY1998 vehicles. Only minor modifications to air bags have been accomplished to meet the temporary standard. If manufacturers were to redesign for a sled test during their normal design cycle, the resulting vehicles could perform at a level that maximizes their performance in the sled test, rather than in the 30 mph frontal barrier test.

The first approach examined existing data broken out by delta-v. Target populations (unrestrained front-outboard occupant potential fatalities) and lives saved were computed for 4 different delta-v categories. These data produced estimates of different effectiveness rates for each speed category. This analysis reveals higher effectiveness rates for the speed groupings nearest the speed levels where testing was required in most of the on-road fleet. Current tests are conducted at 30 mph, and effectiveness is lowest for speeds under 20 and over 31 mph, and highest in the range of 21-30. Based on the crash loads that occupants received in the tests, the sled test is considered to be roughly the equivalent of a 22-25 mph rigid barrier perpendicular (0 degree) crash test impact. Therefore, if manufacturers were to design their vehicles to a sled test, it would be the equivalent of designing them to a requirement that is at least 8-5 mph slower than the 30 mph frontal barrier tests that were required in pre-MY 1998 vehicles. Note that the 25 mph rigid barrier test is more stringent than a sled test, particularly when ± 30 degree oblique tests are added. To estimate the results of such a redesign, each speed category was reduced by 8-5 mph, while effectiveness rates were held constant. New target populations were then derived for each new speed category, and the resulting benefits were calculated by applying the realigned effectiveness rates to their corresponding target populations. Since the new designed air bags were assumed to affect only the unrestrained occupants in frontal crashes, the target population included only the unrestrained front-outboard occupant potential fatalities. In Table VI-27, this process and its results are shown assuming the sled test is equivalent to the 25 mph rigid barrier test. The calculation indicates that 214 fewer fatalities would be prevented if vehicles were designed to a sled test standard. Using the same process, the sled test would prevented 288 less fatalities if it is assumed to equate a 22 mph rigid barrier tests. Overall, under this approach, about 214 to 288 lives would not be saved by air bags designed to just pass the sled test. Note that effectiveness rates in Table VI-27 were based on 1993-1998 CDS. The 1998 CDS was included in the analysis to increase the sample of air bag cases.

Table VI-27
Impact of the Sled Test Under Approach 1
Assuming Sled Test is Equivalent to the 25 mph Rigid Barrier Test

If All Vehicles Had Pre-MY 1998 Air Bags (Passing the 30 mph, Rigid Barrier Test with 50th Percentile Males)				**If All Vehicles Had New Designed Air Bags (Passing the Existing Sled Test with 50th Percentile Males)**				
Delta V	Effectiveness	Target* Population	Lives Saved	Delta V	Effectiveness	Target* Population	Lives Saved	Benefits/ Disbenefits
0-20	0.145	1,919	278	0-15	0.145	1,159	168	
21-25	0.305	2,069	631	16-20	0.305	760	232	
26-30	0.213	2,468	526	21-25	0.213	2,069	441	
31+	0.154	6,113	941	26+	0.154	8,581	1,321	
Total		12,569	**2,376**	Total		12,569	**2,162**	**-214**

Data Source:1993-1998 CDS, 1997 FARS
* Unrestrained front-outboard occupant potential fatalities based on 1997 FARS.

The second approach compared the results of 22-25 mph unrestrained and 30 mph unrestrained tests for matching make/model vehicles. The ratio of these test results was then used as a proxy measure for the differences that might be attained if the standard were an unrestrained 22-25 mph test. This is a mathematical approach that assumes that if air bags were designed to a 22-25 mph standard (sled test equivalent) instead of a 30 mph standard, it would attain the same compliance margin at 22-25 mph that it actually achieved at 30 mph (400 HIC) and the 30 mph test result would be the ratio between 30 mph and 25 (or 22) mph. See Table VI-28 for an example of the assumptions used in this analysis.

Table VI-28
Example of Methodology Under Approach 2

HIC	**Actual Values for Vehicle Designed to 30 mph Test**	**Assumed Values for Vehicle Designed to 25 mph Test**
25 mph unrestrained test	200	400
30 mph unrestrained test	400	800

For vehicles designed to a 25 mph rigid barrier test, the adjustment ratios were derived based on two 1999 vehicles, the Dodge Intrepid and the Toyota Tacoma in unbelted 30 mph rigid barrier tests with 50^{th} percentile male dummies. The averaged ratio was then applied to the 30 mph rigid barrier tests on pre-MY 1998 vehicles to derive new risk probabilities. The loss in benefits were derived by comparing the new risks from higher HIC and chest g's values to the baseline measures of HIC and chest g's. Only HIC and chest g's values were used since no Nij values were recorded for pre-MY 1998 vehicles.

Under this approach, the loss in benefits could be as much as 397 lives assuming reduced benefits above 25 mph for unrestrained occupants. If benefits were assumed up to 30 mph, the loss in benefits be as much as 219 lives.

Due to lack of test data, the adjustment ratio for vehicles designed to pass the 22 mph rigid barrier tests was scaled proportionally based on the crash impact speed. In this case, the sled tests would save between 388 and 514 fewer lives. Overall, under this approach, the sled tests would reduce safety benefits by from 219 to 514 lives.

The third approach examines air bag size. One potential consequence of continuing to allow the generic sled test, instead of the 30 mph rigid barrier test, is that manufacturers could reduce the size of the air bag. Also, as discussed in Chapter VIII, certain tests would promote the use of wider air bags than other tests. For example, the 30 mph oblique test results in the dummy moving off at an angle rather than coming directly into the air bag. Thus, it promotes the use of a wider air bag. In the 35 mph offset test, the dummy goes forward into the air bag and then rotates to the side. This test also promotes the use of a wider air bag, but probably not quite as wide as the oblique test. The agency believes that air bags that are smaller in width could have a negative impact on safety.

One of the findings of the NHTSA evaluation of air bags[6] was that air bags were very effective in purely frontal (12 o'clock) impacts (30 percent effective), but were not as effective in partially frontal (10,11,1, and 2 o'clock) impacts (5.5 percent effective for passenger car drivers and 7 percent for light truck drivers). An update of this data for passenger car drivers, using an

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[6] "Fatality Reduction by Air Bags, Analyses of Accident Data Through Early 1996", NHTSA, DOT HS 808 470, August 1996.

additional year of FARS data, shows that effectiveness decreases as the crash moves further away from direct frontal impacts - 31 percent effective at 12 o'clock, 9 percent effective in 11 and 1 o'clock impacts and 5 percent effective at 10 and 2 o'clock (the effectiveness at 11 and 1 and 10 and 2 o'clock are not statistically significant).

One of the potential countermeasures for reducing the aggressivity of air bags is to reduce the size of the air bag. If the air bag is smaller, it takes less power to inflate it. For a dual stage air bag, the smaller size of the air bag affects both inflation stages, allowing both stages to be less aggressive. This could bring air bag designs closer to meeting the low risk deployment thresholds.

The potential negative safety impact of having an air bag that is not as wide as the pre-MY 1998 air bags is that occupants could move around the air bag in impacts that are not directly frontal and strike the A-pillar or other hard point with their head. Thus, a smaller air bag could have reduced or no effectiveness in partially frontal impacts. The 30 mph oblique test, with its requirement to meet the standard "at any angle up to 30 degrees" from the perpendicular to the line of travel, helps to assure that occupants will not exceed the head injury criteria in partially frontal impacts. The sled test has no angular component and cannot address the same crash condition.

The agency examined air bag data supplied by the manufacturers as a result of a NHTSA special request for information. Of 46 driver side MY 1998 systems, 3 had decreased air bag volume (measured in liters -- an average of 18 percent) and one had increased air bag volume compared to MY 1997 air bags of the same make/model. The decrease in air bag volume was the result of decreasing the depth of the air bag.

Of 42 passenger side MY 1998 systems, 10 had decreased air bag volume (an average of 23 percent, and one had increased air bag volume). On the passenger side, most of the air bags that decreased volume decreased depth, and 8 out of 10 also decreased the width of the air bag. This shows some propensity to reduce air bag volume as a strategy to reducing the aggressiveness of air bags, particularly on the passenger side.

Based on the estimated effectiveness of air bags in pure frontals (31 percent) and in partial frontals (9 percent for 11 and 1 o'clock impacts and 5 percent for 10 and 2 o'clock impacts), an estimate can be made of the lives saved by air bags in partial frontals using the following formula and numbers from the FARS files:

$$3{,}253 = C[1{,}092(1/(1-0.31) - 1) + 419(1/(1-0.09) - 1) + 245(1/(1-0.05) - 1)]$$

where:

3,253 = the total estimated number of lives saved by air bags if all vehicles had air bags

C = a constant used to bring estimates made from the FARS file to date to a total fleet of air bags

1,092 = the number of fatalities in the FARS files to date that were analyzed in determining the 31 percent effectiveness in pure frontal impacts

419 = the number of fatalities in FARS files to date that were analyzed in determining the 9 percent effectiveness in 11 and 1 o'clock partial frontal impacts

245 = the number of fatalities in FARS files to date that were analyzed in determining the 5 percent effectiveness in 10 and 2 o'clock partial frontal impacts

The results of these calculations are:

3,253 = C[491 + 41 + 13)

C = 5.97

The estimated number of lives saved in pure frontals is 2,931 (5.97 x 491). Of these lives saved, 2,169 were unbelted and 762 were belted occupants. And,

The estimated number of lives saved in partial frontals is 322 [5.97 x (41 + 13)]. Of these lives saved, 245 were unbelted and 77 were belted occupants.

Thus, **if** all air bags (driver and passenger side) were changed to only provide benefits in pure frontals, the only test mode in the sled test, there could be as many as 245 unbelted lives that would not be saved by air bags per year, once all vehicles were equipped with these air bags in partial frontal impacts (about 186 drivers and 59 passengers). The 245 lives could be broken up into 186 at 11 and 1 o'clock, and 59 at 10 and 2 o'clock.

By adjusting the results in approaches 1 and 2 to be in just pure frontal (12 o'clock) crashes, about 195 to 477 more unbelted lives would not be saved in pure frontal crashes by air bags designed to just pass the sled tests. Together, adding the lives not saved in approaches 1 and 2 in pure frontal crashes to the lives not saved in approach 3 in partial frontal impacts, about 440 to 722 lives saved by pre-MY 1998 air bags would not be saved by the redesigned air bags that maximize their performance in the sled test. Based on the discussion in Chapter V of the reasons why the sled test does not do a good job of simulating crash conditions and the potential loss of benefits of vehicles designed to a sled test, the agency has decided not to propose this alternative test procedure in the SNPRM.

2. Impact of Rigid Barrier 25 mph Unbelted/35 mph Belted Tests

This section discusses the safety impacts of air bags that are designed only to meet (1) the 25 mph rigid barrier unbelted perpendicular and ±30 degree oblique tests, and (2) the 35 mph rigid barrier perpendicular belted tests.

The 25 mph rigid barrier test is more stringent than a sled test, especially when ±30 degree oblique tests are added. Based on the first two approaches described in the previous section, 214 to 397 lives involved in high speed crashes would not be saved if air bags were designed to meet the 25 mph rigid barrier and oblique unbelted tests. The two approaches were based on the CDS data analysis and the injury performance outcome of the dummies in the crash tests. These two approaches do not depend on a specific air bag design.

In contrast, in the third approach, it was assumed that air bag size (both width and depth) would be smaller, if they were designed only to pass the sled tests, which have no oblique test. Due to a lower impact speed (25 mph vs 30 mph), the air bags would have less depth (see Table V-4). It is unlikely that the air bags would have less width (see Table V-4), because of the ±30 degree oblique test requirement. Therefore, this approach is not particularly meaningful.

Overall, 214 to 397 lives saved by pre-MY 1998 air bags would not be saved by air bags designed only to meet the 25 mph rigid barrier unbelted perpendicular and $\pm$30 degree oblique tests.

The 35 mph rigid barrier belted tests are more stringent than any belted test proposed in the SNPRM and thus would accrue additional benefits. Pre-MY 1998 NCAP test data were used to estimate the benefits of these tests. Based on 69 vehicles (MY 1996 and 1997 NCAP tests), 65.2 percent of the vehicles passed the proposed injury criteria in a 35 mph belted rigid barrier test (in MYs 1998-99 about 72 percent of the vehicles passed). Typically, only one injury criterion was not passed and by a small margin, thus, the benefits of going from the test values down to the level of the proposed injury criteria performance limits resulted in minimal benefits. The theory and procedures to derive the benefits were described in the methodology section (Section B). Note there were no 35 mph rigid barrier (NCAP-type) tests on 5th percentile females. The analysis uses Transport Canada 30 mph rigid barrier tests on 5th percentile females to calculate the reduction rates for the 35 mph rigid barrier tests. The 35 mph belted tests with 50th percentile males would save an estimated 0 to 5 additional lives, while the same tests with 5th percentile females would save 6-8 additional lives. Together the 35 rigid barrier belted tests would save 6-13 belted occupants.

The above methodology assumes that the smallest changes possible are made to bring vehicles into compliance with a 35 mph belted test. Overall, if <u>all</u> air bags were designed only to meet the

25 mph rigid barrier and oblique unbelted and the 35 mph rigid barrier belted tests, 201 to 391 lives saved by pre-MY 1998 air bags would not be saved.

3. MAIS 2-5 Injuries

The MAIS 2-5 injury reduction percentages are shown in Table VI-5-B. Benefits are derived by applying the reduction percentages to the appropriate injury target population as shown in Table VI-29.

Table VI-29
Target Populations for Improved Occupant Protection From High Speed Crash Tests
Front-Outboard Adult Occupant MAIS 2-5 Injuries in Frontal Crashes

	Injuries Represented by 50th Percentile Male			Injuries Represented by 5th Percentile Female			Injuries Potentially Impacted by Improving Sensor Algorithm		
	Head	Neck	Chest	Head	Neck	Chest	Head	Neck	Chest
Drivers	52,043	3,470	27,756	11,424	762	6,093	9,533	636	5,084
Belted	29,640	1,976	15,808	6,506	434	3,470	5,429	362	2,896
Unbelted	22,403	1,494	11,948	4,918	328	2,623	4,104	274	2,188
Passengers	10,933	729	5,831	6,150	410	3,280	2,566	171	1,368
Belted	6,326	422	3,374	3,559	237	1,898	1,484	99	792
Unbelted	4,607	307	2,457	2,591	173	1,382	1,082	72	576
Total	62,976	4,199	33,587	17,574	1,172	9,373	12,099	807	6,452
Belted	35,966	2,398	19,182	10,065	671	5,368	6,913	461	3,688
Unbelted	27,010	1,801	14,405	7,509	501	4,005	5,186	346	2,764

Source: 1993-1997 CDS; 1997 GES.
Note: MAIS 2-5 injuries were derived from 1993-1997 CDS and adjusted to 1997 GES CDS equivalent level.

Table VI-30 shows the injury reduction benefits. An air bag passing the 30 mph rigid barrier test with unbelted 50th percentile males and meeting the proposed ICPLs would reduce 6 to 17 MAIS 2-5 injuries. An air bag that passes the 30 mph, rigid barrier unbelted 5th percentile test would reduce 47 MAIS 2-5 injuries, while one passing the 30 mph rigid barrier, belted 5th percentile female test would reduce 62 MAIS 2-5 injuries. The 25 mph offset, belted 5th percentile female test would reduce 201-330 MAIS 2-5 injuries. The 22 to 35 mph, offset unbelted 50th percentile male tests together would reduce 34 MAIS 2-5 injuries; the same tests with 5th percentile females would reduce 271-400 MAIS 2-5 injuries.

Table VI-30
MAIS 2-5 Injuries Reduced by Test Types for
Improved Occupant Protection From High Speed Crash Tests

		Head	Neck	Chest	Total
18 to 30 mph, Rigid Barrier, 0 and ± 30 Degree Unbelted 50th Percentile Male	**Drivers**	0 (0)	0	0	0* (0*)
	Passengers	17 (6)	0	0	17 (6)
	Total	17 (6)	0	0	17 (6)
Up to 30 mph, Rigid Barrier, 0 and ± 30 Degree Belted 50th Percentile Male	**Drivers**	0 (0)	0	0	0* (0*)
	Passengers	0 (0)	0	0	0* (0*)
	Total	0 (0)	0	0	0* (0*)
18 to 30 mph, Unbelted 5th Percentile Female**	**Drivers**	0 (0)	32	7	39 (39)
	Passengers	0 (0)	4	4	8 (8)
	Total	0 (0)	36	11	47 (47)

* No additional benefits beyond those already achieved from Pre-MY 1998 air bags.
** The unbelted injury reduction percentage is assumed to be identical to that of belted.

Note: Parenthetical values based on lognormal HIC curve, non parenthetical values based on Prasad/Mertz HIC curve.

Table VI-30 - Continued
MAIS 2-5 Injuries Reduced by Test Types for
Improved Occupant Protection From High Speed Crash Tests

		Head	Neck	Chest	Total
Up to 30 mph, Belted 5th Percentile Female	**Drivers**	0 (0)	43	9	52 (52)
	Passengers	0 (0)	5	5	10 (10)
	Total	0 (0)	48	14	62 (62)
Up to 25 mph, Offset, Belted 5th Percentile Female	**Drivers**	0 (0)	105	0	105 (81)
	Passengers	216 (87)	9	0	225 (73)
	Total	216 (87)	114	0	330 (201)
22 to 35 mph, Offset, Unbelted 50th Percentile Male	**Drivers**	0 (0)	34	0	34 (34)
	Passengers	0 (0)	0	0	0 (0)
	Total	0 (0)	34	0	34 (34)
22 to 35 mph, Offset, Unbelted 5th Percentile Female	**Drivers**	0 (0)	160	0	160 (160)
	Passengers	216 (87)	24	0	240 (111)
	Total	216 (87)	184	0	400 (271)

* No additional benefits beyond those already achieved from Pre-MY 1998 air bags.
** The unbelted injury reduction percentage is assumed to be identical to that of belted.
Note: Parenthetical values based on lognormal HIC curve, non parenthetical values based on Prasad/Mertz HIC curve.

Benefits of an air bag system (e.g., the multi-stage inflation system) for improved protection are discussed if the air bag passed either of the alternative options. As noted earlier, Alternative #1 includes the following tests: a) 18 to 30 mph rigid barrier, 0 degree unbelted 50th percentile males and 5th percentile females, b) up to 30 mph rigid barrier, 0 degree belted 50th percentile males and 5th percentile females, c) 18 to 30 mph rigid barrier, $\pm$ 30 degree oblique unbelted 50th percentile males, d) up to 30 mph rigid barrier, $\pm$ 30 degree oblique belted 50th percentile males, and e) up to 25 mph offset belted 5th percentile females tests. Alternative #2 includes a) up to 30 mph rigid barrier belted 50th percentile males and 5th percentile females, b) up to 30 mph rigid barrier, $\pm$ 30 degree oblique belted 50th percentile males, c) up to 25 mph offset belted 5th percentile females tests, and d) 22 to 35 mph offset unbelted 50th percentile males and 5th percentile females tests.

A fleet of vehicles with air bags passing Alternative #1 would save 70-78 lives and prevent 342-482 MAIS 2-5 injuries; and a fleet of vehicles with air bags passing Alternative #2 would save 85-93 lives and prevent 366-495 MAIS 2-5 injuries. However, the 30 mph rigid barrier unrestrained tests in Alternative #1 are replaced by the 22 to 35 mph offset unrestrained tests in Alternative #2. These tests are less stringent in the perpendicular crash mode. Thus, there may be a loss in benefits in the perpendicular crash mode for unrestrained occupants. As a result, the estimated benefits might be smaller than reported for air bags passing Alternative #2. Due to data limitations, the analysis does not yet estimate these potential disbenefits.

D. Benefits Summary

This section provides several tables to summarize the fatality/injury benefits discussed above.

Tables VI-31 and VI-32 provide estimated fatality and injury benefits for the proposed tests.

Table VI-31
Estimated Incremental Lives Saved Annually by Test Type
Compared to Pre-MY 1998 Air Bag Systems*

Tests	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
Suppression When Presence	NA	18	73	NA	91
Suppression When Out-of-Position	45	NP	102	16	163
Low Risk Deployment	21	17-18	91-92	14-15	143-146
18 to 30 mph, 0 and ± 30 Degree Unbelted 50th Percentile Male	0**	NP	NP	0**	0**
Up to 30 mph, 0 and ± 30 Degree Belted 50th Percentile Male	0**	NP	NP	0**	0**
18 to 30 mph, 0 Degree Unbelted 5th Percentile Female	9	NP	NP	1	10
Up to 30 mph, 0 Degree Belted 5th Percentile Female	5	NP	NP	1	6
Up to 25 mph Offset, Belted 5th Percentile Female	49	NP	NP	5-13	54-62
22 to 35 mph Offset, Unbelted 50th Percentile Male* **	17	NP	NP	0	17
22 to 35 mph Offset, Unbelted 5th Percentile Female	67	NP	NP	12-20	79-87

Sled Tests******	-519 to -133	8	72	-162 to -40	-601 to -93

NP: Not proposed test for this group.
* Not all of these test types are additive, see Tables VI-33 and VI-35.
** No additional benefits beyond those already achieved from Pre-MY 1998 air bags.
*** Due to data limitations, the Pre-MY 1998 baseline may not be appropriate for this offset test alternative.
**** Not proposed in the SNPRM; Air bags passing these tests would deploy with less force than MY 1998 redesigned bags, and thus, would benefit the at-risk occupants.

Table VI-32
Estimated Incremental MAIS 2-5 Injuries Reduced Annually by Test Type
Compared to Pre-MY 1998 Air Bag Systems*

Tests	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
Suppression When Presence	NA	9	140	NA	149
Suppression When Out-of-Position	37	NP	195	14	246
Low Risk Deployment	20	7-8	149	11	187-188
18 to 30 mph, 0 and ± 30 Degree Unbelted 50th Percentile Male	0**	NP	NP	6-17	6-17
Up to 30 mph, 0 and ± 30 Degree Belted 50th Percentile Male	0**	NP	NP	0**	0**
18 to 30 mph, 0 Degree Unbelted 5th Percentile Female	39	NP	NP	8	47
Up to 30 mph, 0 Degree Belted 5th Percentile Female	52	NP	NP	10	62
Up to 25 mph Offset, Belted 5th Percentile Female	127	NP	NP	100-229	227-356
22 to 35 mph Offset, Unbelted 50th Percentile Male* **	47	NP	NP	0	47
22 to 35 mph Offset, Unbelted 5th Percentile Female	185	NP	NP	119-248	304-433

NP: Not proposed test for this group.
* Not all of these test types are additive, see Tables VI-34 and VI-36.
** No additional benefits beyond those already achieved from Pre-MY 1998 air bags.
*** Due to data limitations, the Pre-MY 1998 baseline may not be appropriate for this offset test alternative.

The following tables show estimated benefits for the air bag systems: a generic system without multi-stage inflation, the multi-stage inflation system, and the multi-stage inflation system with a 54 pound weight suppression option. Tables VI-33 and VI-34 show the benefits for air bag systems meeting Alternative #1. Tables VI-35 and VI-36 list the benefits for air bag systems meeting Alternative #2. As shown in these tables, an air bag without multi-stage inflation would save 70-78 lives and prevent 342-482 MAIS 3-5 injuries if it passed Alternative #1. The multi-stage inflation system with a 54 pound weight sensor suppression option would save 218-226 lives and reduce 561-701 MAIS 3-5 injuries if the first stage passed the low-risk deployment test for infants, children, and adults and the second stage passed Alternative #1.

Among those air bag systems passing Alternative #2, a generic air bag system without multi-stage inflation would save 85-93 lives and prevent 366-495 MAIS 2-5 injuries. The multi-stage inflation system with a 54 pound weight suppression option would save 224-232 lives and reduce 578-707 MAIS 2-5 injuries. Overall, an advanced air bag would have the potential to save 70-226 lives and prevent 342-701 MAIS 2-5 injuries if it passed Alternative #1; 85-232 lives and 366-707 MAIS 2-5 injuries if it passed Alternative #2. As noted earlier, the 30 mph rigid barrier unrestrained tests in Alternative #1 are replaced by the less stringent 22 to 35 mph offset unrestrained tests in Alternative #2. Thus, the estimated benefits might be smaller than reported for air bag systems passing Alternative #2.

Table VI-33
Estimated Incremental Lives Saved Annually
by Air Bag Systems Passing Alternative #1

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation	63	0	0	7-15	70-78
Multi-Stage Inflation System Based on Crash Severity and Belt Use	80	18	99	19-27	216-224
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	80	18	101	19-27	218-226

Table VI-34
Estimated Incremental MAIS 2-5 Injuries Reduced Annually
by Air Bag Systems Passing Alternative #1

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation	218	0	0	124-264	342-482
Multi-Stage Inflation System Based on Crash Severity and Belt Use	229	7-8	181-182	132-272	549-691
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	229	9	191	132-272	561-701

Table VI-35
Estimated Incremental Lives Saved Annually
by Air Bag Systems Passing Alternative #2

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation	72	0	0	13-21	85-93
Multi-Stage Inflation System Based on Crash Severity and Belt Use	84	18	99	21-29	222-230
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	85	18	101	21-29	224-232

Table VI-36
Estimated Incremental MAIS 2-5 Injuries Reduced Annually
by Air Bag Systems Passing Alternative #2

Air Bag Systems	Drivers	Passengers			Total
		RFCSS	1-12 Years Children	Adult	
A Generic System without Multi-Stage Inflation	237	0	0	129-258	366-495
Multi-Stage Inflation System Based on Crash Severity and Belt Use	245	7-8	181-182	133-262	566-697
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	245	9	191	133-262	578-707

E . Sensitivity Study #1, Safety Belt Use

This section estimates the change in benefits that could result from increased safety belt use. Based on a state survey, in 1997, the average national belt usage rate in that period was 66.9 (base year usage rate from state surveys) percent. The analysis examines air bag benefits at a increased belt usage rate of 85.0 percent which corresponds to an 18 percentage point increase over the base rate.

To estimate the benefits of advanced air bags at the 85.0 percent belt use rate, the analysis needed to adjust the baseline target population to reflect the impact of increased belt use. Then, the procedure was applied as stated in previous sections, to derive the new benefit of advanced air bags. NHTSA's belt usage software (BELTUSE) program[7] (Blincoe, 1994) was used to derive the incremental benefits. The target population for at-risk and improved occupant protection were input to the program to calculate the incremental safety benefits. The BELTUSE program estimated that 24 fatalities and 36 MAIS 3-5 injuries for at-risk groups and 2,316 adult fatalities and 39,958 adult MAIS 2-5 injuries for improved protection would be saved or prevented by increasing belt use from the base 66.9 percent to 85.0 percent. The difference between the baseline population and the incremental safety belt impacts is the adjusted baseline population.

The new benefits of advanced air bags were derived by applying those reduction rates/percentages (Table VI-4-A to VI-5-B) to the adjusted population. Table VI-37 to VI-42 summarizes the estimated benefits for proposed tests and air bag systems at the 85.0 percent belt use rate. At the 85.0 percent belt use rate level, the advanced air bag could potentially save 61-

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[7]. PC-DOS based software. The program also can be ran under the Microsoft Window environment.

196 lives and prevent 292-598 MAIS 2-5 injuries if it passed Alternative #1, and save 73-201 lives and prevent 320-614 MAIS 2-5 injuries if it passed Alternative #2. As noted earlier, the 30 mph rigid barrier unrestrained tests in Alternative #1 are replaced by the less stringent 22 to 35 mph offset unrestrained tests in Alternative #2. Thus, the estimated benefits might be smaller than reported for air bags passing Alternative #2.

Table VI-37
Estimated Incremental Lives Saved Annually by Test Type
Compared to Pre-MY 1998 Air Bag Systems*
at 85.0 Percent Belt Use Rate

Tests	**Drivers**	**Passengers**			**Total**
		RFCSS	**1-12 Years Children**	**Adult**	
Suppression When Presence	NA	18	62	NA	80
Suppression When Out-of-Position	38	NP	87	14	139
Low Risk Deployment	18	17-18	78-79	13	126-128
18 to 30 mph, 0 and ± 30 Degree Unbelted 50th Percentile Male	0**	NP	NP	0**	0**
Up to 30 mph, 0 and ± 30 Degree Belted 50th Percentile Male	0**	NP	NP	0**	0**
18 to 30 mph, 0 Degree Unbelted 5th Percentile Female	7	NP	NP	1	8
Up to 30 mph, 0 Degree Belted 5th Percentile Female	5	NP	NP	1	6
Up to 25 mph Offset, Belted 5th Percentile Female	42	NP	NP	5-12	47-54
22 to 35 mph Offset, Unbelted 50th Percentile Male* **	14	NP	NP	0	14

22 to 35 mph Offset, Unbelted 5th Percentile Female	57	NP	NP	10-17	67-74
Sled Tests****	-421 to -106	8	61	-131 to -32	-483 to -69

NP: Not proposed test for this group.
* Not all of these test types are additive, see Tables VI-39 and VI-41.
** No additional benefits beyond those already achieved from Pre-MY 1998 air bags.
*** Due to data limitations, the Pre-MY 1998 baseline may not be appropriate for this offset test alternative.
**** Not proposed in the SNPRM; Air bags passing these tests would deploy with less force than MY 1998 redesigned bags, and thus, would benefit the at-risk occupants.

Table VI-38
Estimated Incremental MAIS 2-5 Injuries Reduced Annually by Test Type
Compared to Pre-MY 1998 Air Bag Systems*
at 85.0 Percent Belt Use Rate

Tests	**Drivers**	**Passengers**			**Total**
		RFCSS	**1-12 Years Children**	**Adult**	
Suppression When Presence	NA	9	118	NA	127
Suppression When Out-of-Position	32	NP	166	12	210
Low Risk Deployment	17	5	127	9	158
18 to 30 mph, 0 and ± 30 Degree Unbelted 50th Percentile Male	0**	NP	NP	4-11	4-11
Up to 30 mph, 0 and ± 30 Degree Belted 50th Percentile Male	0**	NP	NP	0**	0**
18 to 30 mph, 0 Degree Unbelted 5th Percentile Female	26	NP	NP	6	32
Up to 30 mph, 0 Degree Belted 5th Percentile Female	52	NP	NP	10	62
Up to 25 mph Offset, Belted 5th Percentile Female	109	NP	NP	85-195	194-304

22 to 35 mph Offset, Unbelted 50th Percentile Male* **	40	NP	NP	0	40
22 to 35 mph Offset, Unbelted 5th Percentile Female	157	NP	NP	101-211	258-368

NP: Not proposed test for this group.
* Not all of these test types are additive, see Tables VI-40 and VI-42.
** No additional benefits beyond those already achieved from Pre-MY 1998 air bags.
*** Due to data limitations, the Pre-MY 1998 baseline may not be appropriate for this offset test alternative.

Table VI-39
Estimated Incremental Lives Saved Annually
by Air Bag Systems Passing Alternative #1
at 85.0 Percent Belt Use Rate

Air Bag Systems	**Drivers**	**Passengers**			**Total**
		RFCSS	**1-12 Years Children**	**Adult**	
A Generic System without Multi-Stage Inflation	64	0	0	7-14	61-68
Multi-Stage Inflation System Based on Crash Severity and Belt Use	68	18	84-85	17-24	187-195
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	68	18	86	17-24	189-196

Table VI-40
Estimated Incremental MAIS 2-5 Injuries Reduced Annually
by Air Bag Systems Passing Alternative #1
at 85.0 Percent Belt Use Rate

Air Bag Systems	**Drivers**	**Passengers**			**Total**
		RFCSS	**1-12 Years Children**	**Adult**	
A Generic System without Multi-Stage Inflation	187	0	0	105-222	292-409
Multi-Stage Inflation System Based on Crash Severity and Belt Use	196	7-8	154-155	113-230	470-589
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	196	9	163	113-230	481-598

Table VI-41
Estimated Incremental Lives Saved Annually
by Air Bag Systems Passing Alternative #2
at 85.0 Percent Belt Use Rate

Air Bag Systems	**Drivers**	**Passengers**			**Total**
		RFCSS	**1-12 Years Children**	**Adult**	
A Generic System without Multi-Stage Inflation	62	0	0	11-18	73-80
Multi-Stage Inflation System Based on Crash Severity and Belt Use	72	18	84-85	18-25	192-200
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	72	18	86	18-25	194-201

Table VI-42
Estimated Incremental MAIS 2-5 Injuries Reduced Annually
by Air Bag Systems Passing Alternative #2
at 85.0 Percent Belt Use Rate

Air Bag Systems	**Drivers**	**Passengers**			**Total**
		RFCSS	**1-12 Years Children**	**Adult**	
A Generic System without Multi-Stage Inflation	209	0	0	111-221	320-430
Multi-Stage Inflation System Based on Crash Severity and Belt Use	216	7-8	154-155	116-226	493-605
Multi-Stage Inflation System Based on Crash Severity With a 54-Pound Weight Sensor	216	9	163	116-226	504-614

F. Sensitivity Analysis #2, Redesigned Air Bags

As shown in Table II-5, based on the minimal amount of data available for MY 1998 redesigned air bags, the estimated 181 at-risk fatalities with pre-MY 1998 air bags could be estimated to be about 60 fatalities with redesigned air bags.

Table VI-6 showed that all 18 infants in RFCSS in the target population for pre-MY 1998 air bags could be saved with suppression, low risk or multi-stage inflator systems. Similarly, all 10 infants in RFCSS in the target population for redesigned air bags could be saved.

Tables VI-7 to VI-10 show that somewhere between 91 and 102 children 1-12 years old lives could be saved out of the total target population for pre-MY 1998 air bags of 102. We have not estimated this number using current test data on redesigned air bags yet, but it will probably be in the 27 to 30 lives range out of a target population of 30.

For drivers, suppression could save all 45 fatalities in the target population for pre-MY 1998 air bags, while low risk deployment could save 21 fatalities. Table VI-12 shows that an estimated 39 of 45 out-of-position driver fatalities could be reduced by multi-stage inflators. Based on the target population of and test results from redesigned air bags, suppression could save all 15 fatalities; the low risk deployment could save 6 fatalities (38.36 percent of the target population); and the multi-stage inflators could save about 13 lives.

For adult passengers, suppression could save all 16 fatalities in the target population for pre-MY 1998 air bags, while low risk deployment could save 14-15 fatalities. Table VI-14 shows that an estimated 15 of 16 out-of-position driver fatalities could be reduced by multi-stage inflators. Suppression, and probably all of the technologies, could save all 5 fatalities in the target population for redesigned air bags (Table II-5).

In summary, the majority of the remaining out-of-position fatalities with redesigned air bags would be saved by technologies developed to pass the proposed tests. Assuming low risk deployment air bags for the drivers, 48 to 51 of the projected 60 occupant fatalities could be saved. Assuming multi-stage inflations, 55 to 58 of the projected 60 occupant fatalities could be saved.

G. Discussion

A system that reduces the air bag deployment frequency in the lower speed crashes by raising the deployment threshold might minimize the lower speed air bag induced fatalities. However, industry has argued that, because it takes longer to sense a higher speed crash this could increase the number of occupants being improperly positioned especially in higher severity crashes and result in less effective air bags. To compensate for this effect, more efficient sensors and sensor algorithms would be needed. Presumably, manufacturers would not raise deployment thresholds without improving sensors to offset any significant loss in time due to a higher threshold. The agency does not recommend specific solutions, but provides a variety of tests to allow manufacturers to find the best countermeasure.

As for the suppression systems, one potential concern in disabling the right front passenger air bag when no one or a low weight person is in the right front seat is in not having an air bag for an unbelted driver who could slide to the right and strike the right instrument panel or right side A-pillar. There are a small number of cases without air bags in the NASS files where a crash at 2 or 3 o'clock resulted in an unbelted driver being thrown across the vehicle to the right front side, where the driver sustained injuries. Potentially an air bag could provide benefits in this situation. The agency does not know of a case where an air bag has actually provided a benefit in this type of crash, but it is theoretically possible. Therefore, there could be some small loss in safety for unbelted drivers by suppressing the right front passenger air bag.

The benefit estimates are based on the assumptions that all vehicles in the on-road fleet are equipped with air bags and there are no changes in occupant demographics, driver/passenger behavior, belt use, child restraint use, or the percent of children sitting in the front seat. Behavior modification or changes through public education and safety awareness campaigns could have a positive impact on occupant safety and thus affect the potential benefits of advanced air bags. One such change is increasing safety belt usage. As shown in the sensitive study, at 85 percent belt use rate, the benefits of the advanced air bags would less, yet still a great number of fatalities and injuries can be saved or prevented.

In addition, if more children ride in the back seat, fewer children would be killed by air bags. The child fatalities that advanced air bags are intended to eliminate would thus be smaller in number. However, if labels and education result in more children sitting in the rear seat, the agency is concerned that this rulemaking to decrease the threat of injury from air bags in the front seat could result in the belief by many members of the public that the front seat is now safe for children, and more children would then sit in the front seat. The fatality rate is 22 percent lower in the rear seat than the front seat for all occupants and 27 percent lower for children up through age 12. Since air bags are about 11 percent effective overall for occupants over 12 years old, the safety of all occupants (adults and children) is enhanced by sitting in the rear seat. Education efforts will continue to try to keep children in the rear seat. The agency requests comments on ways to address this potential problem.

Another change might be that short or older drivers would be willing to make seating adjustments so that they are as far away from the steering wheel as possible and still feel comfortable while driving. This could also reduce the number of air bag induced fatalities and the corresponding potential benefits of advanced air bag systems.